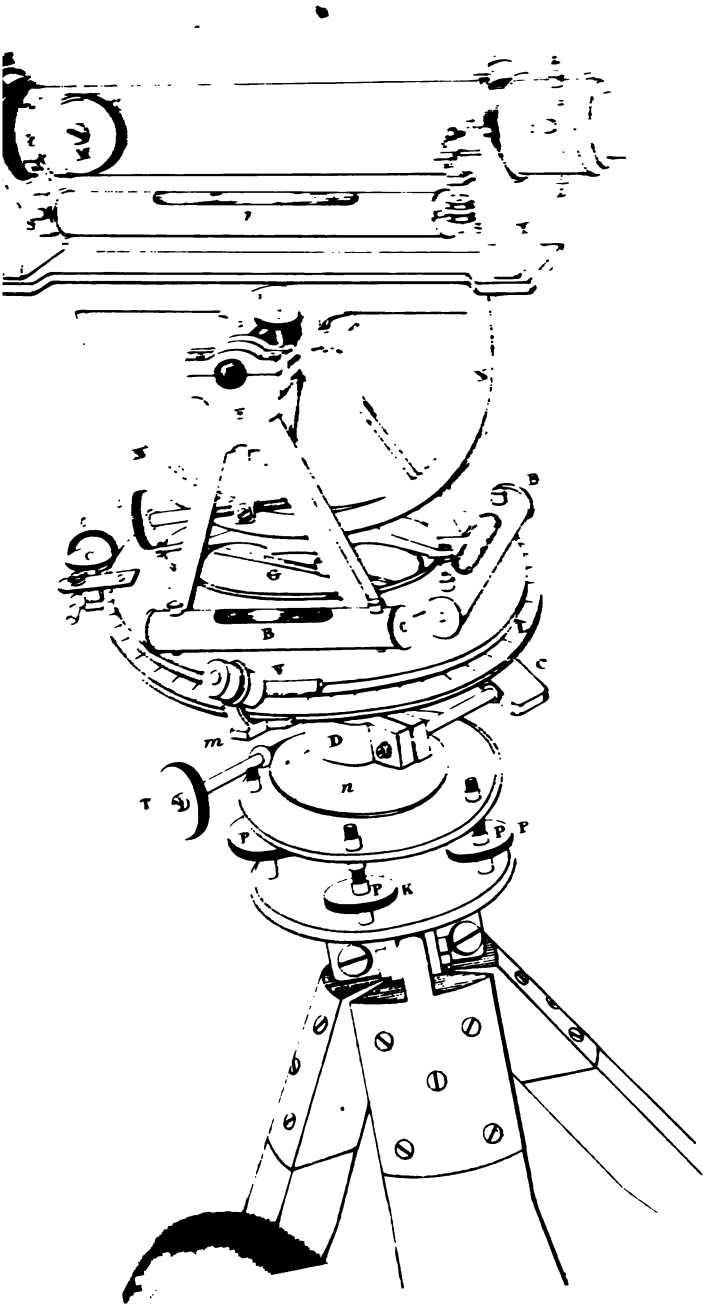
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ELEMENTARY

TEXT BOOK

FOR

YOUNG SURVEYORS AND LEVELLE

WITH

COPIOUS FIELD NOTES, PLANS, AND DIAGRAMS,

PREPARED EXPRESSLY FOR THE USE OF

SCHOOLS AND COLLEGES.

BY HENRY JAMES CASTLE

SURVEYOR AND CIVIL ENGINEER:

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TO

JOHN C. BIRKINSHAW, ESQ.,

CIVIL ENGINEER, ETC. ETC.,

AS A SINCERE BUT HUMBLE ACKNOWLEDGMENT

OF THE MANY

KINDNESSES RECEIVED AT HIS HANDS,

WHILE EMPLOYED UNDER HIM IN THE FIELD,

This Work

IS, WITH EVERY WISH FOR HIS FUTURE HAPPINESS

AND PROSPERITY,

RESPECTFULLY INSCRIBED BY HIS SINCERE FRIEND,

AND OBLIGED SERVANT,

THE AUTHOR.

PREFACE.

This book has been prepared expressly for the use of the upper forms in schools and colleges. The school works, hitherto in use, have been scarcely so much *works on surveying*, as compendiums of mensuration, heights and distances—subjects, which may be fully understood, without the student being in the smallest degree enlightened as to the *best methods of practical surveying adopted in the present day*. And whatever small portion of their contents may have been devoted to Land Surveying (properly so called), they are faint and imperfect sketches of bad systems long since exploded; going, it is true, upon the old and favourite plan of accumulation, or of working from part to whole—that of "*adding field to field and acre to acre*,"—but producing a distorted representation of the positions of each, and a very incorrect sum total of the whole. This system has been found to be so very defective, and the opposite one,

of working from *whole to part*, has so entirely superseded it, that whatever little a lad may have learned of Surveying at school by the *old* method, has to be unlearned again, before he can clearly imbibe the *new*.

In introducing this new system in the present work, which is respectfully but confidently submitted to the notice of the public, the Author has therefore endeavoured, and he hopes successfully, to present it in a form, suited from its simplicity to the understanding of the young, and explained and illustrated with such diagrams and practical field notes (arranged in the way adopted by surveyors in the field) as cannot fail to impress the principles indelibly on their minds.

The subjects treated of here will be found to go *beyond* what are generally introduced in school books; but in treating briefly upon many subjects, and explaining the first principles of each method of Surveying, whether by the CHAIN, THEODOLITE, or CIRCUMFERENTOR, or lastly that of LEVELLING, the Author has considered, that in going fully and minutely into their *first principles*, he has better consulted the interest of the student, than in taking up any *one* subject, and dwelling upon it to the exclusion of the rest, more amply than the young mind can at an early age properly comprehend.

The work is divided, like the Author's larger work, into

four heads: the Chain, Theodolite, and Circumferentor Surveying; and Levelling, treated simply but fully, so that the student can, if deemed necessary, at once proceed to the study of the larger work, which treats upon the several subjects more practically and scientifically.*

The examples attached to each Rule are such, that the pupil, who carefully studies them, cannot help becoming master of the subject—he will certainly have nothing to *unlearn*, should he afterwards follow it professionally.

It seems almost unnecessary to offer any apology for writing a work of this kind in the present day, when the necessity of keeping pace with the times, and of making the education of the young more practical and scientific than has hitherto been the custom, is taken into consideration. The field application of the principles of surveying must inevitably tend, by the use of the various instruments alone, to give a tone to the mind, and encourage a fondness for science, at the same time that it presents to the understanding the usually dry subject of the mathematics in a much more familiar and interesting form than could be done without it.

Nothing is more pleasing to youth, than learning acquired by the use of the eyes. A problem explained and carried

* Castle's "Engineering Field Notes." Simpkin and Co.

out before them, will be impressed on the mind much more clearly and permanently than one that is merely addressed to their understanding.

The Author can now speak from experience. He has proved from the number of copies sold of the work that the opinion which he expressed in a former Edition was perfectly correct, viz., that at one time or other in places of education this subject would become a favorite one.

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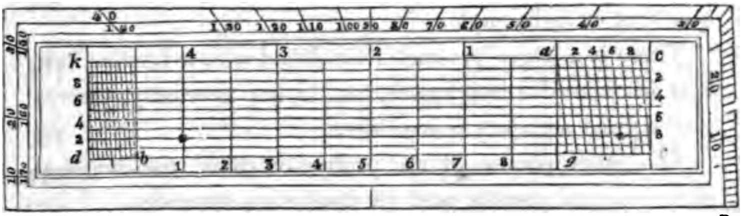
INTRODUCTION.

PROTRACTOR.



A B

DRAWING INSTRUMENTS.

The box of instruments should contain a pair of dividers; compasses, with lengthening bar, and pen and pencil; a bow-pencil and bow-pen; an ivory protractor, as shewn in the annexed drawing; a twelve-inch ivory or box scale, with a two-inch offset scale to match.

The protractor is used for angular measurement—thus, suppose it were required to take off an angle of 60° (see Geometrical Problem No. 3, p. 7), at the point A, place the protractor, so that its centre A should coincide with, or fall upon A, and the line AB upon the line AB. It will be observed, that the degrees are numbered both ways round the protractor. An angle may therefore be taken either from left to right, or from right to left, as the case may require; but as it is divided only to degrees, the minutes must be guessed at. Now to lay off the given angle of 60 degrees from the line AB, look for 60°, counting from

right to left, and make a mark on the paper at C. A line drawn from A through C will make with the line AB the required angle of 60°, which is termed the angle BAC or CAB, the centre letter always signifying the angular point. Any other angle may be taken in the same way—thus, the angle BAE would be an angle of 90 degrees, called a quadrant or right angle.

There is a larger protractor furnished with a vernier, but it is an expensive instrument, and is not necessary, except where great accuracy is requisite.

The inner portion of the protractor called the diagonal scale of equal parts is used for measuring distances.

It is arranged for two scales, the one (called the scale of forty) being either 4, 40, 400 chains, yards, or feet, to the inch; the other (called the scale of twenty) being either 2, 20, or 200 chains, and each of these parts is subdivided into ten. Now, if the larger divisions be called chains, each of the small divisions, as seen at either end of the scale, will be ten links. The whole of the upper line of the diagonal scale will read six chains, or 5·90 chs., 5·80 chs., &c., according as you contract the compasses by one or more of these ten divisions on the right.

The lower line will read 12 chs., or 11·90, 11·80, &c., as you contract them on the left.

For anything less than 10 links the other intermediate horizontal lines must be used; the distances upon them being determined by the intersection of the diagonal lines at either end. Now looking at the upper line (scale of twenty) where the large divisions number from right to left, it will be seen clearly that, if from 1 to *a* be one chain, one *yard, one foot*, &c., then from *a* to 1 in the smaller division

is ·10 or $\frac{1}{10}$ of one chain or yard—from *a* to $_{2}$ is ·20, or $\frac{2}{10}$; from *a* to $_{6}$ is ·60 or $\frac{6}{10}$; and that from 1 of the larger divisions to $_{2}$ of the smaller is therefore 1·20; from 1 to $_{6}$ is 1·60; and so on.

To mark off, therefore, any distance given you in units and tenths, extend the compasses from the larger division corresponding to the given unit, to that of the smaller division corresponding to the tenths, whether these units be chains, yards, &c. This distance measured on the top line will be the distance required.

Again, by following any diagonal line downwards (scale of 2) it will be seen at the bottom to become $\frac{1}{10}$ more to the right than it was at the top—that is, in the whole breadth of the scale 10 links or hundredths of the unit are gained; now as this breadth is divided into 10 equal parts by intermediate horizontal lines, at one line down, it will be ·01 or $\frac{1}{100}$, or (one link, if the unit is a chain); at two lines down, ·02 or $\frac{2}{100}$ (two links), and so on; the numbers of the horizontal lines are marked at each end.

Hence, for the chains (scale of 2), look from *a* to *k;* for the nearest 10 links, from *a* to *c;* and for the odd links, look downwards from *c* to *f;* thus:—

Example. If it be required to measure off 4 chains 68 links (4·68 chains), to the scale of 2 chains to the inch; look for the first figure of the links (6) at the top of the diagonal divisions, then pass the eye down the diagonal line, and observe where it meets the horizontal line opposite the other figure 8; place one leg of the compasses on this point, and open them till the other leg extends to where the perpendicular line drawn from the 4 chains at the top

intersects the same horizontal line. This will be the distance required.*

The protractor is also generally furnished with a scale of chords, offering another method of measuring angles. This scale is constructed on the principle, that a chord of 60 degrees equals the radius of the circle; the mode of using this will be shown in Problem 3 in Geometrical Problems.

---

* Note.—This distance is marked in the diagram by two small circles (o) at the two points answering to the given distance.

DEFINITIONS.

A point has neither length, breadth, nor thickness.

A line has length without breadth.

A plane, or superficies, has length and breadth only.

A solid has all three—length, breadth, and thickness.

An angle is the inclination of two straight lines meeting in a point.

A right angle is the inclination of one straight line to another, when, if either be produced, the second angle will be equal to the former.

An obtuse angle is greater; an acute angle less, than a right angle.

Parallel lines never meet.

A parallelogram is a four sided figure, having its two opposite sides parallel.

A rectangle is a right angled parallelogram.

A square is an equal sided rectangle.

A rhombus is equilateral, but not equiangular.

A rhomboid is neither equiangular nor equilateral.

A circle is a plain figure bounded by its circumference, every part of which is equidistant from the centre. This distance from the centre is called the radius.

An arc is a portion of this circumference.

The chord of an arc is the straight line, joining the extremities of the arc.

A segment is the space included between the chord and the arc.

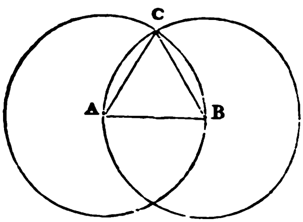
The sector of a circle, is the space included between two radii, and the arc; therefore the sector of a right angle is a quadrant.

GEOMETRICAL PROBLEMS.

1. *To describe an equilateral triangle upon a given line.*

Let AB be the given line.

From A and B, with the radius AB, describe two circles intersecting in C; join AC and BC.

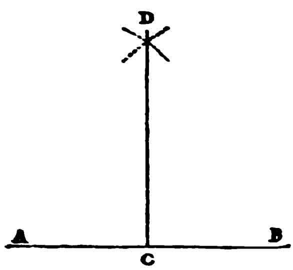


ABC is the equilateral triangle required.

2. *From a point, within a given line, to erect a perpendicular.*

Let AB be the given line, and C be the given point.

From C, as a centre, take any distance, CA, and make CB=CA. Then from A and B, as centres, at the distance AB, describe arcs intersecting at D; join the point of intersection at D with the point C.



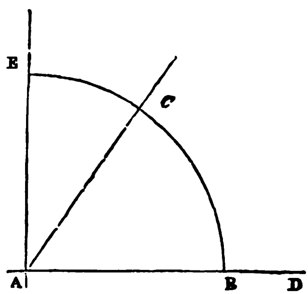
CD will be perpendicular to AB.

3. *At a given point, in a given line, to construct a right*

angle, or an angle of any number of degrees, by means of a scale of chords.

Let AD be the given line, and A the given point.

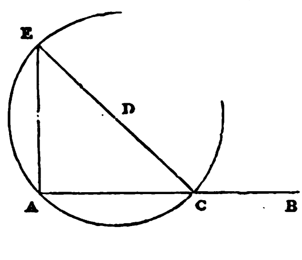
Take off with your compasses (on any scale of chords) AB, the chord of 60 degrees (*radius*); and from the given point A, with that distance, describe a circle intersecting the given line at B; then, from the point of intersection, with the distance of the chord of 90 degrees BE, or of the chord of any other angle that may be required, BC, on the same scale describe another circle, intersecting the former. Join the points of intersection with the given point A, and the lines will be perpendicular to, or making the required angle, with the given line. A protractor may be used, but not so accurately, for the same purpose.



Example 1. At the point A, on the line AB, construct angles of 20, 40, 70, 120, 145, 175, and 179 degrees.

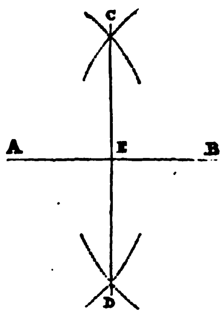
3 a. *From a point* at the end *of a given straight line to erect a perpendicular.*

Let AB be the given straight line, and A the point at the end. Take any point D and from D as centre, at the distance DA, describe the circle EAC, and join CD, and produce to E. Join EA.



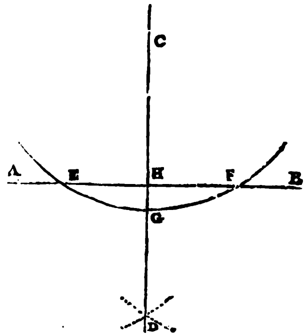
EA will be the perpendicular required.

4. *To bisect a given straight line.*



Let AB be the given straight line; it is required to bisect it. Upon AB describe the equilateral triangles, ACB and ADB; join the vertices C and D by the line CD, intersecting AB at E. E shall be the point of bisection.

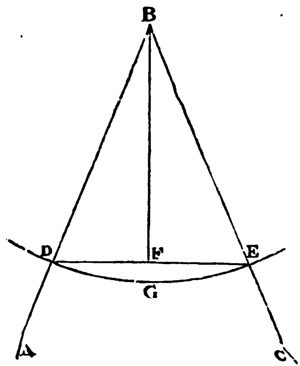
5. *To let fall a perpendicular upon a given straight line, from a given point above it.*



Let AB be the given straight line, and C the given point. From C take any distance CG, and describe the circle EGF, intersecting AB in E and F; bisect EF in H. and join CH.

CH is the perpendicular required.

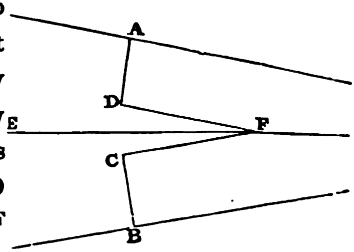
6. *To bisect a given angle.*



Let ABC be the given angle; take any point D in AB, and from B, as a centre, at the distance BD, describe the circle DGE; join DE, and bisect it in F; join BF.

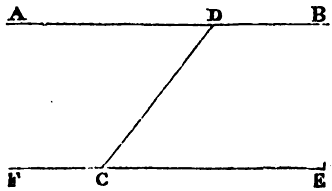
BF shall bisect the angle ABC.

7. *To bisect a given angle, when the* inclination *of the two sides can only be obtained, and not the vertex of the angle, included between them.*



Let A and B be the two sides such, that they cannot be produced. Take any points, A and B, and draw the equal perpendiculars AD and BC; through D and C draw DF and CF parallel to A and B respectively; the angle DFC will be equal and similarly situated to the angle at the vertex. Bisect the angle DFC by the line E F, this line *produced* will bisect the given angle.

8. *To draw a line parallel to a given line.*



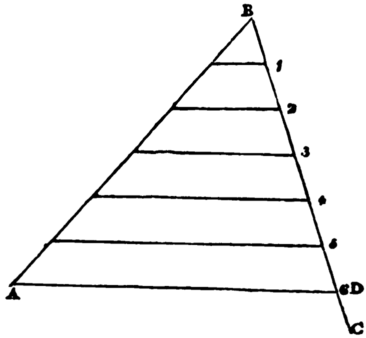
Through the point C to draw a line parallel to the given straight line AB.

Take any point D in AB, join CD, and at the point C make the angle DCE equal to the angle ADC; produce EC to F.

EF shall be *parallel to* AB.

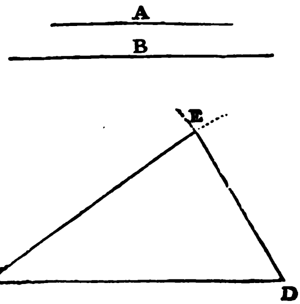
9. *To divide a given line, AB, into any number of equal parts.*

At the point B, making any angle with AB, draw the unlimited straight line BC; take the required number of (six) equal measurements of any length from B towards C, ending at D; join DA, and through the several points on BD, draw lines, parallel to AD, to the line AB; these lines will intersect AB equally, and will be of the required number.



10. *Upon a given base to construct a triangle, whose other two sides shall be respectively equal to two given lines, any two of the lines, however, must be greater than the third.*

Let A and B be the given lines, and CD be the given base; any two of them being greater than the third. It is required to describe upon CD a triangle, whose other two sides shall be equal to A and B.



At the centre C, with the distance CE, equal to B, describe a circle; and at the *centre* D, with the distance DE, equal to A, describe

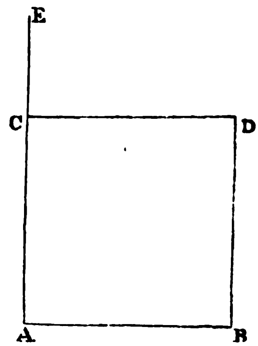
another circle, intersecting the first in E; join EC and ED. CED shall be the triangle required.

EXAMPLE 1. Construct the following triangles, whose sides are respectively, 30, 40, 50; 25, 75, 55; 120, 130, 140; 100, 20, 90; taken upon any scale of equal parts.

11. *To describe a square on a given line AB.*

From the point A erect a perpendicular to AB; make AC equal to AB; and through the point C draw CD parallel to AB; make CD equal to AB, and join BD.

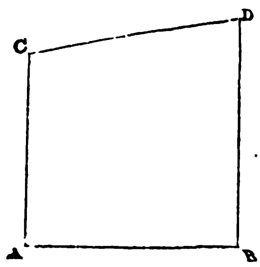
ACDB shall be the square required.



12. *To construct a trapezoid, having its two perpendiculars and its base given.*

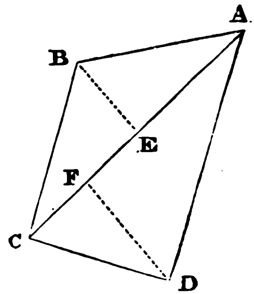
At the points A and B, of the base AB, erect two perpendiculars AC and BD of the given lengths, and join CD.

ACDB shall be the figure required.



13. *To construct a trapezium, ABCD, having the sides and the diagonal given.*

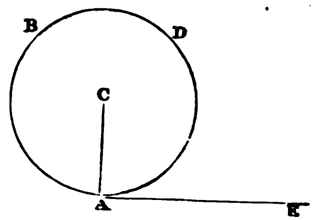
Conceive the trapezium divided into two triangles, ABC and ADC, having the common base AC, which is the given diagonal. Draw the base AC, and upon it, on their respective sides, construct the required triangles (prop. 10) ADC, ABC; having the sides AD, DC; AB, BC, of the required lengths.



ABCD shall be the trapezium required.

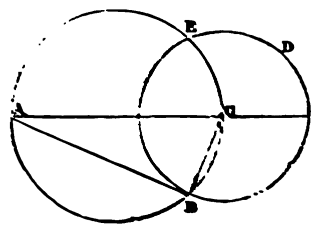
14. *From a given point A,* in *the circumference, to draw a tangent to the circle ABD, whose centre is C.*

Join CA, and make EA perpendicular to AC; EA shall be the tangent required.



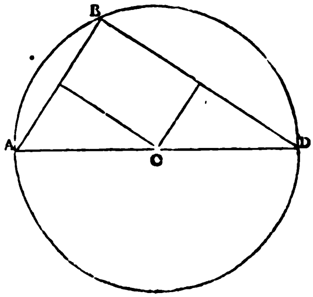
15. *From a given point A,* without *the circumference, to draw a tangent to the circle BED.*

Join AC, and upon AC describe the circle AECB. Join AB. AB shall be the tangent required: for ABC is a right angle, being in a semicircle, and therefore AB is at right angles to CB, which is the radius. Therefore AB is the tangent required.

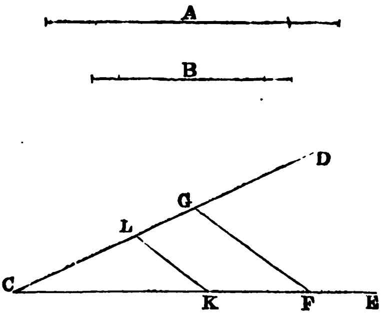


16. *Through the three given points, A, B, D, not in a straight line, to describe a circle.*

Join AB and BD, and bisect them; erect perpendiculars till they meet in C; C will be the centre of the circle.



17. *To find a third proportional to two given lines.*



Let A and B be two given lines. Draw any two unlimited lines, CD and CE, making any angle between them. From CE cut off CF, equal to A; and from CD, CG, equal to B, join GF; again, take CK, equal to CG or B, and through K draw KL parallel to GF. CL is a third proportional to A and B, because by similar triangles, CF: CG:: CK or CG: CL; therefore, if CF be double CG, CG will be double CL.

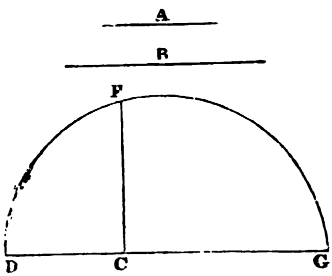
EXAMPLE 1. Find third proportionals to the following lines, viz.: 20, 30; 12, 24; 8, 12; 7, 14.

ANSWER. 45, 48, 18, and 28, respectively.

18. *To find a fourth proportional to three lines.*

Proceed as in the above, but instead of taking CK, equal to CG or B, take CK equal to the third line; then CL in this case also becomes the fourth proportional.

19. *To find a* mean *proportional between two lines A and B.*



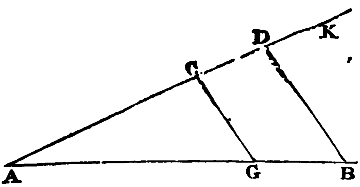
Draw any line DG; make DC equal to A, and CG equal to B; upon DG, as diameter, describe a circle; erect the perpendicular CF, which is the mean proportional required. For DC. $CG = CF^2$.

$\therefore$ DC: CF:: CF: CG and $CF = \sqrt{DC.CG}$.

EXAMPLE 1. Find mean proportionals between 36 and 100; 25 and 36; and 7 and 28.

ANSWER. 60, 30, and 14, respectively.

20. *To divide a given line, AB, into proportional parts.*



Through A draw any unlimited line AK, and take AC and CD of the required proportions; join DB, and through C draw CG parallel to DB. AG and GB, are the parts required.

For, by similar triangles, AC: AD:: AG: AB, and

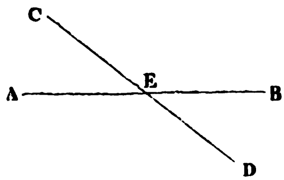
convertendo, AC : (AD—AC) :: AG : (AB—AG); *i. e* AC : CD :: AG : GB.

Example 1. Divide the line AB, whose length is 48, into the following proportional parts, 6 to 2; 7 to 1; and 5 to 3.

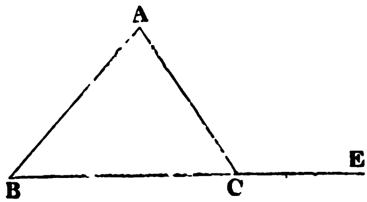
Answer. 36, 12; 42, 6; 30, 18.

USEFUL THEOREMS.

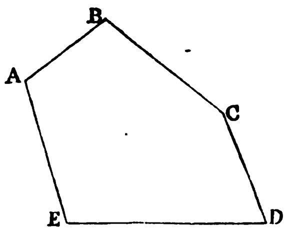
1. If two straight lines cut one another, the opposite angles are equal, and the four angles are together equal to four right angles; *i. e.* the angle AEC is equal to the angle DEB, and the angle CEB to the angle AED. (*Euclid* I, 15.)



2. In any triangle the three interior angles are equal to two right angles; *i. e.*, the angles at A, B and C, are together equal to two right angles. (*Euclid* I, 32.)

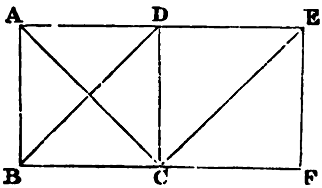


3. All the interior angles of any rectilineal figure are equal to four less than twice as many right angles as the figure has sides; *i. e.* in the five-sided figure ABCDE, all the interior angles at A,B,C,D, and E, are equal to four less than twice five right angles; that is, are equal to six right angles or 540 degrees. (*Euclid* I, 32, *Cor.*

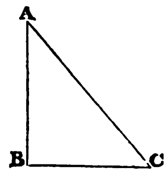


4. The greatest angle of every triangle is opposite the greatest side. (*Euclid* I, 18.)

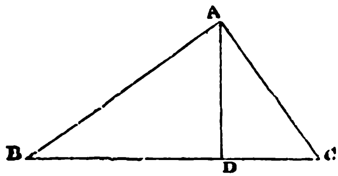
5. Parallelograms and triangles upon equal bases and between the same parallels, that is, having the same perpendicular height, are equal to each other; *i.e.*, the parallelogram ABCD = the parallelogram DBCE; and the triangle ABC = the triangle CFE. (*Euclid* I, 35—38.)



6. In every right-angled triangle, the square of the hypothenuse is equal to the sum of the squares of the base and perpendicular; *i.e.*, in the *right*-angled triangle ABC, $AC^2 = AB^2 + BC^2$.

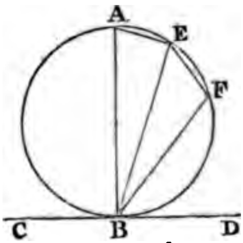


7. In any right-angled triangle, if a line be drawn at right angles to the hypothenuse, this line is a mean proportional between the segments of the hypothenuse; and the base and perpendicular are, respectively, mean proportionals between the hypothenuse and the segment adjacent to them; *i.e.*, $BD.\ DC = DA^2$; $CB.\ BD = BA^2$; and $BC.\ CD = CA^2$. (*Euclid* VI, 8.) Also $BA^2 - AC^2 = BD^2 - DC^2$ or $\overline{BA+AC}.\ \overline{BA-AC} = \overline{BD+DC}.\ \overline{BD-DC}$. (*Euclid* II. 5 Cor.)

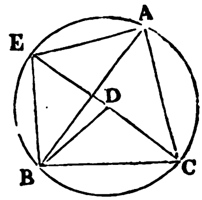


This is a very useful proposition in measuring the width

of a river; one or two practical applications of it will be given in a subsequent part of the work.



9. The angle, in a semi-circle, is a right angle; in a segment, less than a semi-circle, greater than a right angle; in a segment, that is greater, less; *i.e.*, AB being the diameter, the angle AEB is a right angle; the angle EFB, being in a segment less than a semi-circle, is greater than a right angle; and the angle BAE is less. (*Euclid* III, 31.)



10. Angles, standing upon equal circumferences, are equal, whether they be at the centre or the circumference; *i.e.*, if the circumference BE be equal to the circumference BC, the angles EAB, BAC, on the circumference, and the angles EDB, BDC at the centre, are equal; and the angles EDB-BDC are respectively double the angles EAB, BAC. (*Euclid* III, 20 *and* 27.)

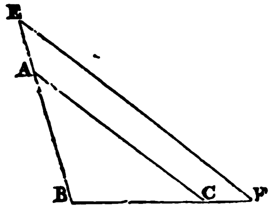
11. If a line touch a circle, any angle made between this line at the point of contact, and a line cutting the circle, is equal to the angle in the alternate segment; *i.e.* (See Fig. 9), the angle CBE equals the angle EFB, and the angle CBA equals the angle AEB. (*Euclid* III, 32.)

12. Parallelograms, and triangles of equal altitude, are as their bases; and of equal bases, are as their altitudes. (*Euclid* VI, 1.) And, when neither are equal, in the com, pound ratio of both; *i.e.*, if there be two triangles whose bases and perpendiculars are as follows: the one base 40,

the other 20; the one height 30, and the other 15; the area of the larger triangle is to that of the smaller, as 40×30 is to 20×15, or as 1200 to 300; or as 4 to 1.

13. Similar triangles have their areas, proportional to the squares of their homologous sides. (*Euclid* VI, 19.)

That is, the area of the triangle EBF is to that of the triangle ABC, as EB^2 is to AB^2, or as BF^2 is to BC^2.



PRELIMINARY OBSERVATIONS.

The statute acre in England consists of ten square chains, that is, of ten square blocks of land, whose length and breadth are one chain each; or, taking the 10 blocks as one whole block, then an acre is equal to the area of a rectangle, whose base is 10 chains and perpendicular 1 chain; or to any other rectangle, the product of whose base and perpendicular also equals 10 chains: thus, 4 chains base with $2\frac{1}{2}$ chains perpendicular, and 2 chains base with 5 chains perpendicular are each equal to 1 acre.

Now the acre being equal to 10 square chains, and each chain containing 22 yards, or 4 poles, we have for the area,

$$(1)^2 \text{ chain} \times 10 = 10 \text{ square chains;}$$
$$\text{or } (4)^2 \text{ poles} \times 10 = 160 \text{ square poles;}$$
$$\text{or } (22)^2 \text{ yards} \times 10 = 4840 \text{ square yards;}$$
$$\text{or } (66)^2 \text{ feet} \times 10 = 43560 \text{ square feet;}$$
$$\text{or } (100)^2 \text{ links} \times 10 = 100{,}000 \text{ square links.}$$

Again, as there are 100 links and 66 feet in a chain,

$$1 \text{ chain} = 100 \text{ links} = 66 \text{ feet} = 792 \text{ inches;}$$
$$\text{hence } 1 \text{ link} = 7{\cdot}92 \text{ or } 8 \text{ inches nearly;}$$
$$\text{and } 1\tfrac{1}{2} \text{ link} = 11{\cdot}88 \text{ inches} = 1 \text{ foot nearly;}$$

hence, *with any quantity less than one chain,* to bring feet into links, add $\frac{1}{2}$ more, *to bring links into feet,* take $\frac{1}{3}$ less.

Again, because the acre equals 160 square poles or perches, and there are 4 roods in an acre, there will be 40 square rods or perches in a rood. These are the aliquot parts of an acre.

PROBLEM I.

To bring acres therefore into roods and perches, multiply by 4 *and by* 40.

EXAMPLE 1. In 8 acres, how many roods?

Answer 32 roods, or 1280 perches.

EXAMPLE 2. In $24\frac{1}{2}$ acres, how many perches?

Answer 3920 perches.

PROBLEM II.

To bring square chains into acres, roods and perches.

As almost all areas are obtained in square chains, by the *multiplication* of one side in chains, by another side in chains,

this is perhaps the most practical case that can be given to a beginner.

Rule. Divide the square chains by 10, to bring them to acres, and then multiply by 4 and 40 as before.

EXAMPLE 1. Let the area of a field equal 8·2500 square chains (that is 8 square chains and 2500 square links). Required the number of acres.

$$
\begin{array}{r|l}
10 & 8{\cdot}2500 \\
\hline
 & 0{\cdot}82500 \\
 & \phantom{0{\cdot}8250}4 \\
\hline
 & 3{\cdot}30000 \\
 & \phantom{3{\cdot}300}40 \\
\hline
 & 12{\cdot}00000
\end{array}
$$

	A.	R.	P.
Answer	0.	3.	12.

EXAMPLE 2. How many acres, &c., will there be in ·8250 chains; and in 82·50 chains.

	A.	R.	P.		A.	R.	P.
Answer	0.	0.	13.	and	8.	1.	0.

The difference depends upon the different positions of the decimal point.

MENSURATION.

PROBLEM I.

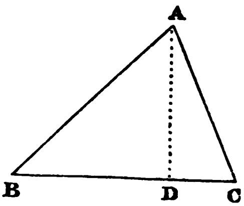
To find the area of a triangle, when the base and perpendicular height are given.

Rule. Multiply the base by $\frac{1}{2}$ the height.

EXAMPLE 1. What is the area of a triangular field, whose base is 5 chains 50 links, and height 3 chains 20 links?

$$5{\cdot}50 \times \frac{3{\cdot}20}{2} = 8{\cdot}8000 \text{ sq. chs.,}$$

and $8{\cdot}8000$ sq. chs. $=$ 0. 3. 20. (A. R. P.)



A. R. P.
Answer 0. 3. 20.

EXAMPLE 2. Required the area of a triangle, whose base is 7 chains 25 links, and perpendicular height 90 links.

A. R. P.
Answer 0. 1. 12.

EXAMPLE 3. How many square yards are contained in a triangular plot of ground, whose base and height measure respectively, 8 chains 50 links, and 5 chains 50 links?

By preceding rule area $= 2{\cdot}3375$ acres.
multiply by the sq. yards in 1 acre $=$ 4840

area $= 11313{\cdot}5$ sq. yards.

PROBLEM II.

To find the area of a triangle, when the three sides are given.

Rule. Take half the sum of the three sides, subtract each side severally from this sum; then multiply this and the three remainders together, and take the square root for the area.

EXAMPLE 1. What is the area of a triangle, whose three sides are 30, 40, and 50 chains?

Answer $= \sqrt{360000} = 600$ sq. chains $= 60$ acres.

EXAMPLE 2. Required the area of a triangular field whose three sides measure respectively 25 chains, 42 chains, and 56 chains?

A. R. P.
Answer 49. 0. 10.

EXAMPLE 3. The three sides of a triangular plot of ground are respectively 20 chains 40 links, 25 chains 20 links, and 30 chains 50 links. What is the area?

A. R. P.
Answer 25. 2. 4.

EXAMPLE. 4. Given the sides of a triangle 24 chains 72 links; 38 chains 75 links; and 44 chains 68 links; to ascertain the area in square yards.

Answer 231384 square yards.

PROBLEM III.

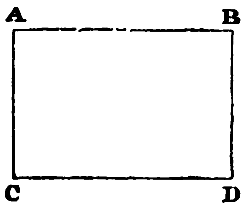
To find the area of a quadrilateral right-angled figure.

Rule. Multiply the length by the breadth, the product will be *the area.*

Example 1. What is the area of a rectangular field, whose length is 35 chains 40 links, and breadth 24 chains 36 links?

chs.		chs.		sq. chs.		acres.
35·40	×	24·36	=	862·34	=	86·234
						4
						·936
						40
						37·440

A. R. P.
Answer 86. 0. 37.



Example 2. Required the area of a right-angled parallelogram, whose length is 56 chains 24 links, and breadth 35 chains 42 links.

A. R. P.
Answer 199. 0. 32.

PROBLEM IV.

To find the area of a trapezoid.

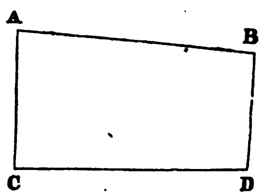
Rule. Multiply half the sum of the two parallel sides by the distance between them.

Example 1. In a trapezoid, whose parallel sides are 7 chains 25 links and 8 chains 63 links, the distance being 11 chains 65 links, how many acres are there?

$$\begin{array}{r|l} & 7{\cdot}25 \\ & 8{\cdot}63 \\ \hline 2 & 15{\cdot}88 \\ \hline & 7{\cdot}94 \end{array}$$

chains. acres.
$7{\cdot}94 \times 11{\cdot}65 = 92{\cdot}50 = 9.250$
4
1·000

A. R. P.
Area = 9. 1. 0.



Example 2. What is the area of a trapezoid, the parallel sides of which are 14 chains 20 links, and 12 chains 35 links, and the distance between them 27 chains 25 links?

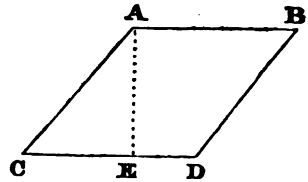
A. R. P.
Answer 36. 0. 28.

Example 3. Required the area of a trapezoidal field whose sides are 40 chains and 27 chains, and distance 15 chains and a half.

A. R. P.
Answer 51. 3. 28.

PROBLEM V.

To find the area of a parallelogram, whose angles are not right angles.



Let ABCD be the parallelogram, whose area is required; let fall the perpendicular AE. The measurement of the parallelogram is AE. CD.

Rule. Multiply the base CD by the perpendicular AE.

Example 1. Required the area of a four-sided regular field, whose sides are 20 chains 15 links, and 16 chains 89 links, and the included angle 30 degrees.

Plot the figure to any scale; its perpendicular height will then be found to be 8·45 chains,

and $20{\cdot}15 \times 8{\cdot}45 = 170{\cdot}265$ square chains.

A. R. P.
Answer 17. 0. 4.

EXAMPLE 2. When the sides are 15 chains, 25 links; and 21 chains 18; and the included angle 45 degrees; what is the area of the field?

	A.	R.	P.
Answer	22.	2.	26.

EXAMPLE 3. With the same sides, but with an angle of 105 degrees, what is the area?

	A.	R.	P.
Answer	31.	0.	31.

PROBLEM VI.

To find the area of a trapezium.

Rule. Divide the trapezium into two triangles by the longest diagonal (see Geometrical Problems, 13th Ex.); take this as the common base of the two triangles, and multiply it by half the sum of the two perpendiculars (BE and FD in the diagram, let fall upon it, from the opposite angles).

EXAMPLE 1. To find the area of a trapezium, whose diagonal is 20 chains, and the two perpendiculars 2 chains 50 links, and 3 chains 40 links.

$$\begin{array}{r|l} & 2{\cdot}50 \\ & 3{\cdot}40 \\ \hline 2 & 5{\cdot}90 \\ \hline \end{array}$$

A. R. P.

Answer $= 2{\cdot}95 \times 20 = 59$ sq. chains $= 5.\ \ 3.\ \ 24.$

EXAMPLE 2. How many square feet of paving are there in a court yard, whose diagonal is 2 chains 64 links, and perpendiculars 95 links and 84 links?

Answer 10292 square feet.

PROBLEM VII.

To find the area of an irregular polygon.

Rule. Divide the polygon into trapeziums and triangles, and find the sum of the areas of each.

Various examples of this will be found in the part on chain surveying.

PROBLEM VIII.

To find the circumference of a circle.

Rule. Multiply the diameter by 3·1416.

EXAMPLE 1. What is the circumference of a circle, whose diameter is 30 chains?

Circumference $= 3{\cdot}1416 \times 30 = 94{\cdot}2480$ chains.

EXAMPLE 2. Required the circumference of a circle, whose diameter is 17 chains 40 links.

Answer 54·66 chains.

EXAMPLE 3. What is the diameter of a circle, whose circumference measures 1,000 chains?

Answer 318 chains 30 links.

PROBLEM IX.

To find the length of any arc.

As 360°: to the given degrees of the arc :: the whole circumference: to the length of the arc required.

EXAMPLE 1. What is the length of an arc of 20°, of a circle, whose circumference measures 850 chains?

As 360°: 20°: : 850 chains : x

$$x = \frac{850 \times 20}{360} = 47{\cdot}22$$

Ans. 47·22 chs.

Example 2. Required the length of the quadrant, the circumference measuring 300 chains.

Answer 75 chains.

Example 3. What is the circumference of a circle, when the arc of 30° measures 17 chains 20 links?

Answer 206·40 chains.

PROBLEM X.

To find the area of a circle.

Rule. Multiply the square of the diameter by ·7854.

Example 1. What is the area of a circular field, whose diameter is 18 chains?

$18^2 \times \cdot 7854 = 254 \cdot 4696$ sq. chains $= 25 \cdot 44696$ acres.

A. R. P.
Answer 25. 1. 31.

Example 2. The area of a circular plot of ground is required, whose diameter is 27 chains.

A. R. P.
Answer 57. 1. 1.

Example 3. What is the area of the circle, that can be described by a rope, measuring $5\frac{1}{2}$ chains, having one end fixed, as a centre?

A. R. P.
Answer 9. 2. 0.

CHAP. I.

ON THE CHAIN.

THE chain, in common use, is called Gunter's chain, from its inventor, and is divided into ten equal parts, distinguished by a piece of brass, with notches; the brass at the first division, from either end, having one notch; at the second division, two notches; at the third, three; at the fourth, four; and at 50 links, or the middle of the chain, there is a round piece of brass.

The object of marking these divisions from either end of the chain, is to enable the surveyor to measure *either way* from each end.

Each of the above brass divisions of the chain is again sub-divided into other ten parts, or links; so that the whole chain is divided into 100 parts, or links; each link therefore $=\frac{1}{100}$ chs $=$ 0·01 chs.; and each 10 links $=\frac{1}{10}$ chs $=$ 0·10 chs.

The advantage of this arrangement is, that, in measuring a line, it matters not whether the distance be termed 7·32 chains (7 *chains* 32 *links,*) or 732 links; and, as 10 square chains make one acre, or 10 times $(100 \text{ links})^2$ or 10 (10000 links) or 100000 square links, it is only necessary to multiply together the length and breadth, given in links, of a piece of ground, whose area is required, and set off *four* decimal places, when the integers will be square chains; or set off *five* decimal places, and the integers will be the required acres.

To measure a straight line with the chain.

In measuring with the chain, it is requisite to have ten small arrows, or pins of strong iron wire, about a foot and a half long, and pointed at one end, to stick in the ground.

A piece of red cloth should also be tied to the ring of each arrow, so that they may be more easily perceived in the midst of grass or underwood.

The surveyor should also be furnished with some half dozen poles six feet high, about an inch diameter, pointed and shod at the bottom, and having a white and red flag, about nine inches square at the top.

Important observations to young beginners.

Having previous ranged the line carefully with these flags, of which there should be at least three to every long line, let one assistant take the lead, who is called the *leader*, having the ten pins and the chain-handle in his left hand, and proceed toward the mark at the end of the line; while the other assistant, called the *driver*, holding the other end of the chain also in his left hand, keeps it close against the mark or starting point; when the leader has come to the end of the chain, let him turn round with his face towards the driver, and, taking one of the arrows in his right hand, let him pull the chain tightly, keeping it on the ground, and put down the arrow he held in his right hand close against the chain-handle outside.

As the chain is seldom straight at first, when the leader faces the driver, the driver must always keep *his* end to the ground, close to the mark; but the leader, previously to finally setting the arrow, should raise the chain with both

hands, shake it to the very end, and before he puts his arrow down, see that it is perfectly straight.

The leader must also observe, as he is putting down the chain, to look towards the driver, to see if he is himself in the right direction, or whether the driver is noting him to the right or to the left; when he has succeeded in hitting the right direction (which he knows by the driver calling out "*down*"), and, obtaining the proper measurement of the chain, by carefully complying with the directions above, and has put his first arrow down, he must *return* the cry of "*down*" to the driver, and, taking the chain up in his right hand, must proceed onward until the driver, coming to the first arrow, cries out "*stop*," when the same process is repeated. The leader having a second time returned the cry of "*down*," the driver picks up the arrow, carrying it in his left hand, taking care, as long as he has two or more flags to cover before him, to direct the leader; when the leader, however, has past all but the last flag, the proper position of the arrows depends upon himself, which he must carefully do, by covering the backward flags.

When the leader has put down the ten pins, he calls out "*tally*," and the driver, dropping his end of the chain, comes up to the place, picks up the last arrow put down, counts over the whole of the arrows, and, putting his foot to the mark, returns them again to the leader, who finding they are the right number (10), proceeds with the chaining as before; the second "*tally*" is then called; then the third; each cry to prevent mistakes, being repeated by the driver. The surveyor should also enter each tally in his book.

In this manner they continue, till the whole line is measured. Should it not be a complete chain to the end,

and *no offsets required to be taken*, it is usual for the leader to put his end of the chain down to the mark, and for the driver to read off the distance; but *if there are offsets*, then the driver had better put his end down, and the leader pull up, as the position of the offsets is measured from the driver's end.

CHAP. II.

THE OFFSET STAFF.

(For the Chain.)

Is a narrow slip of deal about $1\frac{1}{2}$ inch wide by 1 inch thick, and generally 10 links long, divided into links; it should be furnished at one end with a small notch or hook, to put the chain through the hedges, and be numbered on both sides, from different ends. It is used for the purpose of measuring short distances, called *offsets*, from the line to the hedges, &c.

As these offsets must be measured at right-angles to the chain, the surveyor should stand *on the opposite side of the chain to the hedge*, or object to be measured to, and walking along the chain, looking at either end, mark where a *perpendicular* from the given object would fall upon the chain.

CHAP. III.

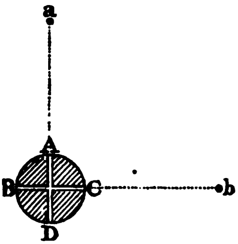
ON THE CROSS STAFF.

The cross staff is about 5 feet six inches high, pointed, and strongly shod, to drive into the ground, having at the top a circular piece of hard wood, so fixed as to be taken on and off.

The wood head is divided into four divisions, by grooves, at right angles, cut about half an inch down into the wood, which is about 2 or 2½ inches thick. This head is sometimes made with a spring, to move up and down the pole of the staff, and to remain firm at any height.

It is always necessary to test the accuracy of these grooves, which can be done in the following way:—

Let ABCD be a cross staff; and AD, BC, its sights, or grooves; place a flag, *a*, in the direction of the groove AD, and another at *b*, in that of BC; half reverse the cross, so that DA point to *b*, and CB to *a*. Then, if the flags are still in the direction of the grooves, the instrument is correct.



The principal use of the cross staff is in the measurement, by perpendiculars, of straight-sided fields; in the setting off of short perpendiculars from a base line; and in the laying out of streets and building lots.

It is useful where no great accuracy is required, when, in the computation of the areas, it is not requisite to take

into account the irregularities of the hedges, as, in *surveying a field*, it saves the necessity of measuring the whole way round, and makes a diagonal, with two perpendiculars from each of the opposite corners, all the admeasurements required.

This instrument was much more in use formerly than it is now, though country surveyors still have recourse to it, when they are employed in measuring farm crops, &c.

CHAP. IV.

THE FIELD BOOK.

The field book should be of a convenient size for the pocket, having the left page ruled with a central column, and the right page left blank for remarks. The central column should be headed "*Chains*," on either side "*Offsets*," and the right page "*Remarks*."

The central column is intended for all actual lines measured, and, by commencing *from the bottom of the page*, the page becomes a smaller representation of the reality with the line measured *from* you, and the offsets, at their respective distances on that line, taken at so many links to the right or to the left, as are actually on the ground. In keeping the field book, it should always be remembered, that the central column is virtually but one line, representing the chain, the space *within* the column being merely

required for the several distances on the chain, whence the offsets are taken; and, *secondly*, that all offsets, are read either way, outward *from* the central column, in the same way as they are measured outwards *from* the chain.

To preserve uniformity, as it is more natural to measure from left to right, the place measured *from*, is put *on the left* of the central column, at the bottom of the line, and the station measured *to*, is put at the top, *on the right;* the points of commencement and termination of the line can thus be immediately seen.

The pages should also be numbered, for facility of reference, before beginning.

If the direction of the line is determined by an angle taken by the theodolite, or the bearing of the line be given by the circumferentor, the angle of the former or the bearing of the latter is placed in the central column, immediately above the starting point.

When the line crosses a road, or hedge, &c., make corresponding lines in the field book, as in Field No. 2, Plate 1, line 731 (page 48), at the distances 685, 695, and 731; which on reference to the plan will be easily understood.

In taking "offsets" to corners of fences, houses, &c., mark the relative position of the corner, as to the chain line (see 6·79 on line 6·90—page 47—and 0·10 on 7·31) in the example of "CHAIN SURVEYING," Field No. 2 (page 48), and generally be careful to make the field book, as much as possible, a *fac-simile* of the ground itself, with every post, hedge, house, &c., placed on the book, as to the central column, considered always as a line, in the same position as they stand to the chain on the ground.

Stations are generally expressed in the field book by the

following character △, which, in the plan, is represented by a circle in pencil, drawn round the station *point*, which should be always that of a needle.

In Chain Surveying, the BASE LINE, perhaps, had better, when referred to, be termed the *base line* AB, in contradistinction to the secondary lines, which are required in surveys of some extent, and are virtually base lines to their own portions of surveys, and may be lettered CD, EF, &c., &c.

But in all other cases, distinguish the lines by their lengths, and the points upon them, by the distance of those points from the zero end of the lines;—thus, in the example of the method of keeping the field book for chain surveying, Field 1, Plate 1, page 42, "*from* 574 *on* 635, *to* 34 *on* 485," the line begins at 574 on 635, and runs to 34 on 485—that is, the measured line is a line, connecting the point (574 on the line 635, measured from the beginning of the line) with the point (34 on the line 485).

And, again, at Field No. 2, page 47, "*from* 685 *on* 731 *to* 574 *on* 635," the point started from, is that point upon the line 731, which is 6 chains 85 links from the beginning of the line, and its termination, a point 574 on another line 635.

In *theodolite* surveying, it is better perhaps to use letters, as the stations are but few, and mostly come within the exceptions above referred to, being generally base lines to smaller portions of survey.

It is usual to take the bearing of the base line at the commencement of the survey, and enter it at once in the field book; the meridian line can then be put upon the estate.

THE BOUNDARIES OF PROPERTY.

The brow of the ditch, or that edge of the ditch which is furthest from the hedge, is the usual boundary of the field. This, however, is not always the case.

The common allowance from the quick root, for the brow of the ditch, varies, in different places, being 5 links, 8, and sometimes as many as 10 links.

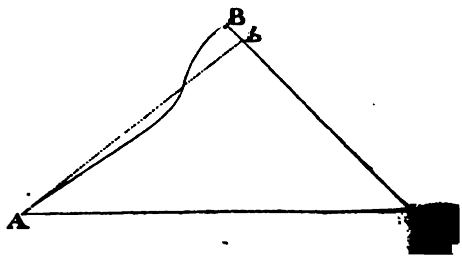
When a stream runs between two properties, the centre divides them. This is the case with a parish ditch, which is generally the water way from the hills.

CHAP. V.

SURVEY OF A FIELD OF THREE SIDES.

Let ABC be a triangular field to be surveyed—the first thing to be ascertained, is, whether a plan is required, or whether the area alone is sufficient.

If only the area, observe whether the sides AB and BC are sufficiently straight and regular to warrant any point *b* to be taken, from which straight lines, drawn to A and C, would approximate suffici-



ently with the area of the given triangle ABC. If t are, arrange the field book in the following manner:

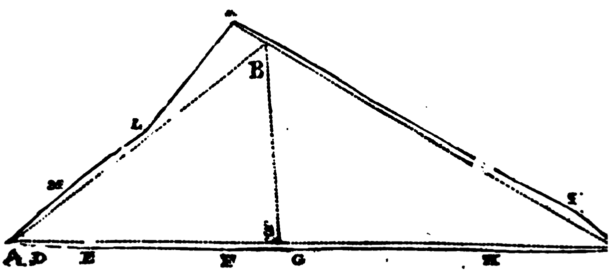
FIELD BOOK.

OFFSET.	CHAIN.	OFFSET.
perp. from 250 on 560	3.15	to *b*.
	5·60	to C.
△	2·50	
from △ A		

NOTES.

Having carefully selected the point *b*, it will only be quisite, in measuring along AC, to observe where a ri angle from (*b*) would fall upon AC, note in the field b 250; leave a mark in the ground, and continue the meası ment to C=5·60. Draw a line in your book, and meas from 2·50 to $b=3·15$; then $\frac{1}{2}$ (3·15)·(5·60)=8·82 squ chains=area of triangle ABC.

If a plan be required, or the hedges AB and BC be irregular as to require offsets being taken, it will be re site, for the sake of the *offsets alone*, to measure round whole field along the three sides. Let the field now assı the form in the accompanying diagram:—



select any points A, B, C, commanding the longest

nearest lines to the several hedges of the field, and place flags at those points A, B, and C.

FIELD NOTES.

From 5·70 on 12·73	4·25	to 8·50 on 9·27
	6·80	0 + D (to 0 on 12·73)
	5·26	8 being △ A
	3·20	4
From 8·50 on 9·27		
ditch—	9.27	— crosses 4 + D
△	8·50	3
	3·20	3
⌉	1·20	14
	0·00	0 + D
From 12·73 on 12·73		
D—	12·73	— + 0 + D to △ C
	10·18	4 + D
	6·15	6
△	5·70	4
	4·82	15
	1·60	5
	·56	4 + D
From △ A	·00	0 + D

First observe, whether the point A be exactly at the ditch; if it is, put in the centre line 0, and in the right hand offset line 0; proceed till you come opposite 56 links, the first corner or bend D; take the offset (4) to D; this line, connected with A, gives the actual position of the ditch. Proceed along the line AC, marking down the several lengths as above, with their respective offsets, and selecting some point S, 5·70, to be noted as a station, whence to measure afterwards, a check to the point B; note it △ (a station) in the *left hand* column, as the check-line will be to the left. Having completed the measurement of the line,

put *where to* in the right offset column at the top, and draw *one* line over the whole; all *loose* lines, that is, lines not connecting certain points, have *one* line only drawn over them: *fixed* lines have *two*. To measure next from C to B, write from 12·73 on 12·73 on the left offset column in your field book, and observe, as before, what the position of the ditch is; it will, of course, be 0, as before, as the station was at the end of the previous line, and the line was measured up to the edge of the ditch, which is denoted by the ditch crossing,—thus; ditch—(12·73)— ×
next mark BA the direction you are going in—whether to the right or to the left, CB being the direction you have just come: BA the way you turn (to the left): proceed, therefore, measuring along CB, and marking the offsets, till you come to B, which enter in your field book 8·50 △, proceed with the measurement to the hedge, making 9·27; put down in your centre column 9·27, offset 4 to the right, and draw a line, thus:—

A——B
   |
   C

hedge——(9·27)——× *i.e. hedge crosses.*

From B measure to A, and as B is 8·50, write in the book, in the left hand column, from "8·50 *on line* 9·27," and proceed as before to A, which is a point 0, or zero, on line 12·73: mark this on the right hand column: and, as this completes the triangle, draw *two* lines above it instead of one. This line is 6·80 chains.

Then, from point 5·70 on line 12·73, measure carefully the check-line to B, being 8·50 on 9·27, and draw *two* lines over it in the field book, writing *check* line across it.

Now to plot the above, draw any line AC equal to 12.73

marking upon it the station S (5·70 chains); from the end of this line 12·73 chains, at the distance of 8·50 chains, describe an arc, and from the beginning of 12·73 chains, with the distance 6·80 chains, describe another arc; their point of intersection B will be the vertex of the triangle ABC; join B to S; BS should measure 4·25 chains. Upon AC, AB, and BC, lay off the requisite offsets, and the field is plotted.

To Measure a Four-sided Field.

This must, in all cases, be divided into two triangles. If *the boundaries are irregular,* each hedge will require a subsidiary line, that is, a line running along the side of it, for the sake of the offsets. A diagonal line must then be drawn from the two opposite corners that are *most remote* from each other, and check lines taken upon it, as in the last case.

If the boundaries are *regular,* the diagonal line alone need be measured, together with the lengths of the perpendiculars from it to each of the other corners.

EXAMPLE 1.

The following field notes, accompanied with a plan (being Field No. 1, in Plate No. 1) of a four-sided field, near Maiden Lane, surveyed in the above manner, are given as an example of the method of keeping the notes in the field, and of plotting the work at home.

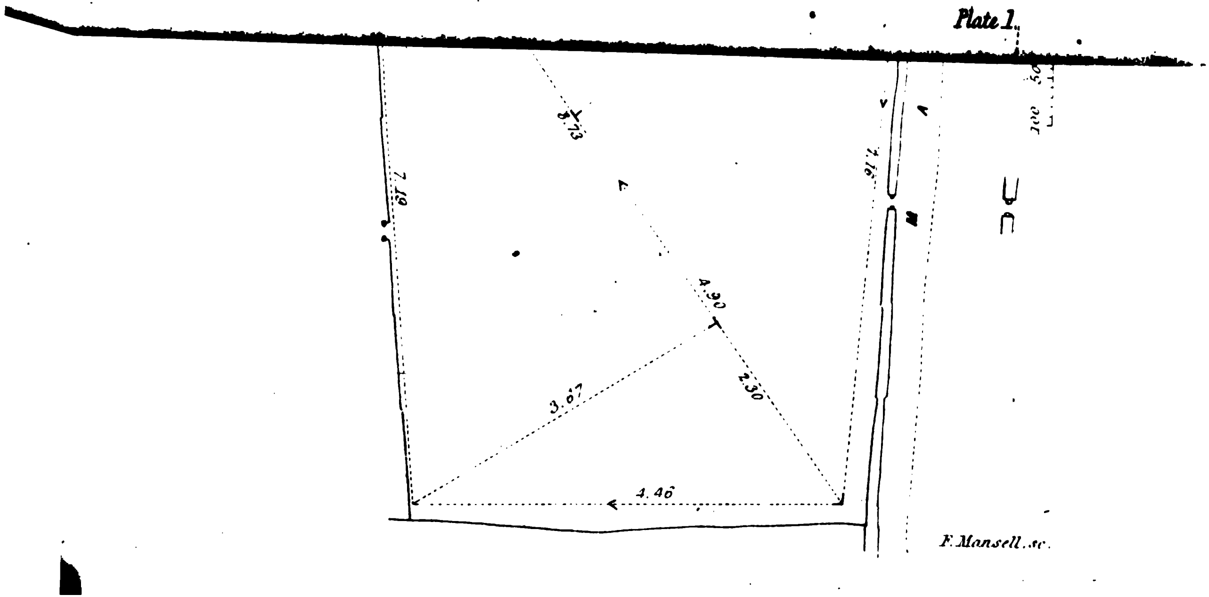
The student should be required to plot every one of the examples of field notes *himself*, for practice, and compare them with the plans given.

☞ Begin at page 43.

FIELD No. 1, Plate 1.

From 230 on 873 check line.	3·67	to 480 on 485
From 490 on 873 check line.	4·71	to 574 on 635
	8·73	to 719 on 724
	4·90	△
△	2·30	
From 34 on 485		
	7·16	to 34 on 485
10+24	7·00	
10+19	5·00	
to gate post 22	3·92	
10+11	3·00	
10+ 7	1·00	
to top of bank 10+ 8	0·00	
From 574 on 635		
Maiden D—	635	— × Lane
Maiden D—	597	— × Lane
top of bank—	587	— ×
	5·74	△
4	500	
2	300	
D+5	100	
to 2nd gate post 12	0·08	
From 719 on 724		

Plate 1.



F. Mansell, sc.

40 40 D—	7·24	— ×
8	7·19	△
7	600	
6	400	
to gate st 10	2·79	
D + 5	1·00	
From 480 on 485		
D —	485	— ×
D + 13	480	△
+ 28	400	
+ 32	300	
10 + 27 D	200	
10 + 28 D	1·00	
10 + 10	0·34	△
10 + 15	0·00	
D —		— ×
Maiden		— Lane

Commencing on top of bank by the road side, at the south-east corner of the field.

On Plotting, Scaling, &c.

Before commencing to plot, it is always requisite to consider carefully the shape of the plan to be plotted, its size and character, and the most desirable position to place it upon the paper, so as to admit of the best vacant space for the insertion of the heading or title, with the usual specification, that should accompany it. It has generally been considered indispensable to place the plan, so as to have the north side of it on the top of the paper fronting you; but, I should *recommend*, the position of the meridian

line to be made but a secondary consideration, and in every case to depend upon the size and shape of the plan; where the two can be united it is better, of course, to do so; though I certainly cannot deem it a matter of so much moment as it is often made.

Having made the scale, lay down your base line very accurately, and draw it carefully in with lake, marking the various stations upon it and its total length. Then take, with the compasses, the various lengths of the sides of the several triangles, of which the survey is composed, and lay off the different points of intersection, testing rigorously, as you proceed, the constructed, with the measured lengths of the respective *check-lines*.

Do all this *before* an offset is put in, unless the offset be afterwards used as the point of a more convenient base line for another triangle.

When this part of the plotting is found correct, draw the lines in very faintly with lake.

In marking off the several distances on the base line, use one of the long scales, and, placing it close against the given line, prick off, with a fine needle, the proper distances, and round the points, as centres, draw a small circle, but on no account use any black lead pencil, however finely sharpened, in any of these stations. Do this also, in determining the point of inclination of the sides of the triangle.

Having finished these subsidiary lines, as they may with propriety be termed, proceed to the laying off the offset points.

The best method of doing this, is to place the long scale, above referred to, close against the given line, having the zero points of each coinciding, and get another person to

ead off the several distances thereon, whence offsets are aken, first going through the right offsets, then the left. The offset scale is now necessary. This is placed against the long scale,* and the lengths on the measured line are determined by the long line, while the distance of any point, or offset therefrom, is determined by the offset scale; this latter point is alone marked. Practice and care will ensure considerable rapidity, as well as accuracy, in this plan.

When the scale is 2 or 4 chains to the inch, any offset less than 10 links, must be guessed at.

Plotting of the Notes to Field, No. 1.

First lay off the measured lines independently of the offsets.

Draw any line AB indefinitely in pencil, as your base line, so placed as to throw the plan into a favourable position on the paper. Now, for the length of this line, by looking at the field notes you will find that the whole line is 4·85; but there is a △ at 34, and another at 480. Upon the assumed line AB measure these △s. 0·34 and 4·80, marking in pencil their distances against them.

On turning to the field notes, it will be found that the next line runs *from* 480 *on* 485, *to the right.* It is 724 long; but the station is at 7·19; draw any line, making the supposed angle with AB, and mark 7·19 against it.

The third line begins at 719 on the last line, and turns to the right, and though continued to 635, across Maiden Lane, has its station point at 5·74; mark this line also in its supposed position.

The fourth line does not say to the right or to the left,

* Leaden weights should be placed on the long scale.

because it runs from a station 574 on 635—the end of the line to a previous station, viz., 34 on 485, which was the starting point; this line is 716 long; mark this distance against it. Thus far these are all loose lines, and might lie in any position.

The next measured line, however, ties them in, it begins at 34 on 485 (the base line), and runs to another previous station, 719 on 724; its total length is 873, and there are two stations upon it, 230 and 490; draw this line in its proper position, and mark off the stations, 230 and 490.

The next two lines are check-lines, the one (471) runs from 490 to 574 on 635; the other (3·67) from 230, to 480 on 485; mark these also.

Having placed these several lines roughly with their given lengths, in their supposed position, proceed to plot them off correctly by triangles, marking in every case, on the plan, the direction the line was measured in on the ground (see plate 1). AB, of course, is the base of the whole. Upon AB lay off a triangle, whose other two sides are 7·19 and 8·73; that is, from 0·34 as centre at the distance 8·73 chains describe an arc, and from 4·80 as centre, at the distance of 7·19 chains describe another arc intersecting the former; complete the triangle and mark upon 8·73 the stations 2·30 and 4·90. Then, to verify the correctness of the work thus far, measure the distance of the station 2·30 from the point B; this, if the work be correct, should be 3·67, the length of the check line.

Next, upon the line 873, lay off another triangle, whose sides are 574 and 7·16; the distance of the previous station 490, from the vertex of this triangle, should, if the work be right, be found 4·71. The whole field is now plotted.

Example 2.

Method of Surveying and Plotting Two Fields Together.

The field in the previous example having been already surveyed, the adjoining field was added to it, which is to be plotted from the accompanying field notes.

FIELD No. 2, Plate I.

from 500 on 868 check line	5·35	to 685 on 731
	8·68	to 609 on 609
from 574 on 635	500	△
	690	to 574 on 635 (Field 1)
⊢ D —	6·79	— ×
10 + 1	600	
10 + 4	400	
10 + 2	100	
to top of bank 10	0·50	0 to D
from 685 on 731		

Maiden { D —	7·31	— × } Lane.
		— ×
D —	6·95	— ×
top of bank —	6·85	— × ▷
10 + 20	6·70	
10 + 36	500	
D		
10 + 70	100	
< 90	0·10	
from 609 on 609		
D 15	609	△
6 + 4	5·82	
......		
D + 4	500	
D + 16	300	
D + 27	100	
to gate post 40	0·50	
D + 30	0·40	
35		
+ 21	·32	
pond		
+ 20	·12	
from 719 on 724		produced.

☞ Having the previous notes of Field No. 1, the following notes were taken for the survey of the adjoining Field No. 2.

Plotting of the Notes to Field No. 2.

The first line measured is 609, it begins at 7·19 on 7·24 which is produced to obtain this distance. Produce the line 7·19 therefore to 609 further, which is a station—then, turning to the right, agreeably to the field book, mark off the distance 685, which is the station point in the next line 731: from this point 685, the distance to a known corner *in the* first field (being 574 on 635), is 690.

Now, 574 on 635 is a known fixed point, and because the line 7·19 of the last survey, is a fixed line, its production is also fixed, and the end 609 is a fixed point; the line joining 5·74 on 635, and this point, is, therefore, also a fixed line. Measure this diagonal line by the scale, and see if its length is 8·68 as it was made in the field, if it is, the whole of the work thus far is right; then its distance, determined in position by joining two fixed points, is checked by its measured distance. Upon this base, therefore, describe a triangle, whose other two sides are 685 and 690, and their intersection is also a fixed point.

Again, by taking the distance 500, upon the diagonal 8·68, and measuring the check line 535, this line, measured from a point in a fixed line, to the intersection of the two other lines, becomes a check upon this triangle.

Having found the plotted check-lines agree with the measured distances, (which shews, that both field and office work are correct,) draw in these chained lines carefully, in *red ink*, and proceed to lay off the offsets.

To lay off the Offsets.

A little attention to this subject will be found useful to the student afterwards.

Take the first Field.

The offsets on the line AB, are all to the left; mark off, therefore, the several offsets in their proper places, observing in the second offset, that $\overset{D\,+\!\!-}{(10+10)}$ is ten links up to the hedge, which, with the ditch, is ten links wide. Mem: Whenever these offsets are referred to in pairs they must invariably be read if they are left hand offsets, from right to left, and *vice versâ*. They are placed here exactly as they

stand in the notes. This determines the position of the

D

hedge to be *within* the field; without the 10, or had it been (D + 10), the hedge would be *beyond* the boundary of the field. At 4·85, the cross ditch of the field intersects the line.

In the next line the offsets are still to the left, and are marked (D + 5), showing that, in this case, the hedge is *without* the field. At 7·19, there is an offset of 8, to where the edge of the side ditch intersects the side of a pond; at 7·24 the cross ditch of the field intersects the line as before. The width of the pond 40 links, and its length 40 links, are marked.

In the next line, the offsets are still to the left, and the (D + 5) shows, that the hedge, in this case is beyond the field. As this line, if produced, will cross Maiden Lane, it is produced across for the purpose of determining its width and position. In every case, in addition to the mere measurement of the field, it is advisable to annex such collateral localities as roads, turnpikes, ponds, &c., as may determine the relative position of the field. At 0·08 there is an offset of 8 links (on the left) to the second gate post. In the following line 716, where the offsets "are still to the left" at 392, there is an offset of 22 to "gate post" only. Observe—that it is usual to take to the *first* gate post, and allowing the average width of gate to be 15 or 16 links, or about 10 feet, to determine the position of the gate by the direction of the line. It is difficult to fix the position without some fixed rule, such as the above, of always taking the *first* point of the gate, as you come to it, on the line, whence the offset is taken.

The first offset on the line 716 is (10+8), always on the left. This 8 is up to the bank bounding the lane, and 10 is the distance to its top. This 10 is repeated throughout, the average width having been taken. The other three lines have no offset to them.

Offsets of Second Field.

The first line is 609, and the first offset is at ·12 (still on the left), being (pond + 20), or, 20 up to the edge of the pond: the second offset at ·32, is (35+21), that is, 21 up to the pond, + 35 across the pond, which, by the accompanying diagram, ends there; the distance ·32 being taken, in order to shew that *there* was the end of the pond.

The next offset is at 40 (D + 30), that is, 30 up to where the ditch of the field goes into the pond; at 50 there is an offset of 40 to first gate post; at 1·00 the offset is (D+27), that is, 27 to the brow of the ditch, which being beyond the boundary of the field, the width of that and the hedge is not required; the other offsets are regular to the distance

D

5·82, which has an offset of (6+4), that is, 4 up to the hedge, and 6 through the hedge, which is now within the field, to the brow of the ditch; the previous offset was (D + 4), that is, 4 to the brow of the ditch (the hedge being then beyond the field), the ditch therefore *changes* at this point, denoted in the diagram by There is here also a cross hedge; on the left, which the diagram shows too.

In the next line, at ·10, there is an offset, taken to the corner of the field, ·90 links; and the relative position of the sides, to the offset line, is expressed by the diagram in the notes, which should be in every case, as much as possible, a gound plan of the locality.

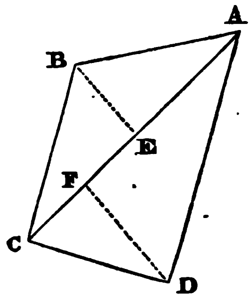
In line 690, at 50 links, the line touches the ditch, having 0 offset to it, the other offsets to this line are all regular.

To the two following lines, being check lines, there are no offsets.

COMPUTATION OF AREAS.

Divide the field into triangles, and find the area of each separately, by measuring the bases and perpendiculars off a scale of equal parts, and proceed according to the rules given in the chapter on mensuration (Prob. 1 & 7.)

Let, for example, the field ABCD be a trapezium, and let it be straight-sided, the area will be equal to $\frac{BE + FD}{2} \times AC$.



Now let the sides be irregular and take the diagram for a triangular field as an example (page 38), then AC multiplied by half the perpendicular let fall upon it from B, will give the area within the triangle ABC (which will be found to be
A. R. P.
2. 2. 27.), but the space included between that figure and

the irregular hedge, has still to be added to complete the area of the field.

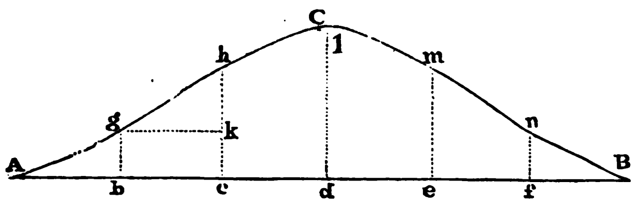
Now to obtain this space, which is made up of as many trapeziums as are included within the several offsets taken upon the line as perpendiculars, find the areas of these trapeziums, by rule (page 26) in mensuration and add their sum to the area of the large triangle for the area of the whole field.

It will therefore stand thus:—

	A.	R.	P.
Triangle	2.	2.	27.
Trapezium on line AC . .	0.	0.	12.
" " BC . .	0.	0.	7.
" " BA . .	0.	0.	24.
Answer Acres	2.	3.	30

Example 2. Take for practice, the field notes of the fields Nos. 1 and 2, Plate No. 1, at pages (42 and 47), and calculate the areas, checking them by the second method.

When the offsets are taken at every chain's length, or at any equal distance, the whole area is equal to the sum of the offsets multiplied into the common distance between them, that is,



the area of ACB $= d\,(bg + ch + dl + em + fn)$.

Example 1. Let d=one chain, and bg, ch, &c., re

tively 10, 15, 17, 14, 9 links, what will be the area of the figure.

	A.	R.	P.
Answer	0.	0	10.

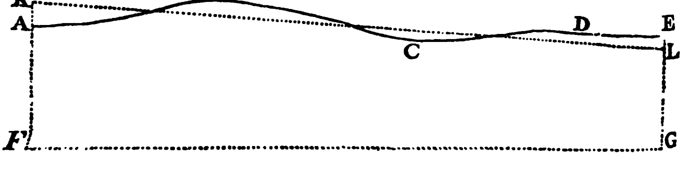
EXAMPLE 2. Given the several offsets 15, 25, 40, 10, 60, 30, 25, 8, 18, 9, 8, 4, 6, 0, taken at one chain's distance. Required the area.

	A.	R.	P.
Answer	0.	1.	0.

THE SECOND METHOD.

A common method in practice, in computing the areas of irregular-sided fields, is to have a piece of transparent horn—and by *giving* and *taking*, as it is termed—to draw a straight-sided polygon, equal to the given irregular one, and to divide this into triangles, then, by means of the compasses and scales, to measure the lengths of the new lines, and from these lengths, and the perpendiculars also measured off the scales,—to calculate the area. This is the common method among the profession, and in good hands tolerably correct. I should, however, recommend young beginners to calculate their areas at first by both methods.

Thus,—Let ABCDE be the irregular outline of a hedge or ditch; by placing along it a straight-sided piece of transparent horn, the position of the line KL can be determined, such that the area KLGF shall be equal to the area of ABCDEGF; by making the pieces taken in at A and C, equivalent to the pieces given up at B and D.

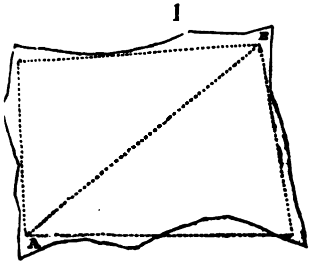


The following examples of Field notes and plans are added for practice. The student had better plot them by the notes and compare them with the plans, and then calculate their areas.

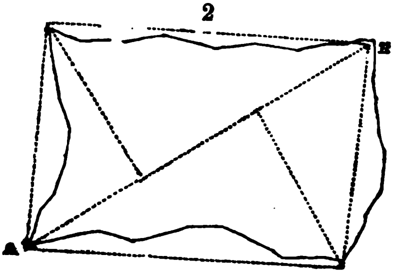
EXAMPLES OF FIELD NOTES FOR PRACTICE.

ALL PLOTTED TO A SCALE OF SIX CHAINS TO THE INCH.

1



2



Note.—The student will remember that these are but Wood-blocks.

DIAGRAM No. 1.

	6·55	43	
——— D	6·50	— ×	
	6·05	32 + D	to B on Base Line
	4·40	10	
	2·90	27	
	2·00	20	
From 846 on 900	1·00	23 + D	

	9·00	57
D——	8·80	—— × ——
	8·46	△ 46
D——	7·95	—— × ——
20 + 15	7·00	
20D + 35	6·24	
20D + 30	5·50	
D——	4·40	—— ×
	3·60	30 + D
	3·00	34 + D
	2·50	23
	2·20	12
	2·00	8
	1·50	12
From A on AB	0·50	37 + D

	6·12	34
D——	6·00	— × 12 + 20
	5·45	to A on Base Line
	4·80	2+20D
	4·10	17+20D
	3·22	3+20D
	2·50	28+20D
	1·36	69+20D
From 7·94 on 820	1·00	43+20D

D——	8·20	—— ×
	8·08	45 + D
	7·94	△
	7·50	35 + D
	7·00	33 + D
	6·00	16 + D
	5·00	6 + D
	4·50	10 + D
	4·00	12 + D
	3·50	17 + D
	3·00	30 + D
	2·35	50 + D
From 956 on 1020	0·40	40 + D

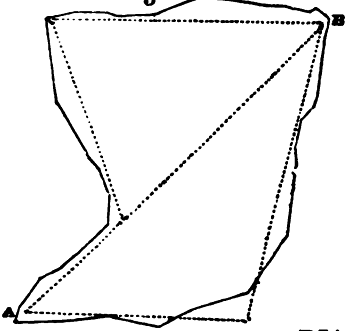
D + 22	10·20	
D——	10·00	—— ×
D + 50	9·56	B △
From △ A on AB		

DIAGRAM No. 2.

	5·67	to 10·12 on 10·16
10	5·55	
Check Line D—	5·45	—— ×
From 8·44 on AB		
	5·70	to 10·10 on 10·10
3	5·50	
Check Line ——	5·48	—— ×
From 4·25 on AB		
	7·20	18
D——	7·10	—— ×
	7·00	to B on AB
	6·00	22
	5·20	40
	4·50	55
	3·50	90
	2·70	94
	1·70	55
From 10·12 on 10·16	1·30	50 + D
D + 14	10·16	
△	10·12	
26	9·50	
17	8·50	
23	8·00	
62	7·20	
76	6·85	
99	6·10	
50	4·00	
42	3·50	
56	2·50	
D + 50	1·60	
From A on AB		

	7·08	to A on Base Line
to corner 8	7·00	
30	6·00	
77	5·00	
100	3·70	
90	3·10	
D + 60	2·35	
D + 54	1·90	
D + 30	1·20	
From 10·10 on 10·10		
	10·10	△
to corner 23	10·00	
35	7·75	
17	6·50	
36	4·80	
D + 17	3·50	
D + 25	2·30	
D + 10	1·00	
D ——	0·55	—— ×
From B on Base Line		
to corner 8	12·82	
D ——	12·75	—— ×
	12·55	to B
	8·44	△
△	4·25	
Corner——	0·08	—— of Ditch
From A on Base Line		

3



4

DIAGRAM No. 3.

D——	9·94	—— ×
	9·85	20 + D
	9·57	to B
	9·35	15
	7·50	34
	7·10	30
	6·50	5
	5·50	15
	5·00	30
	2·85	56 + D
D——	1·72	—— ×
D + 25	1·00	
From 7·00 on 7·00		
	7·00	△
D + 99	6·90	
60	6·00	
20	5·00	
D——	4·70	—— ×
	4·25	25
	3·50	20
	3·00	10
	2·50	5
	1·40	12
	1·00	25
	0·72	30
From A on AB	0·00	35 + D

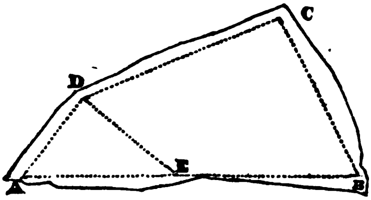
	6·72	to 4·12 on 13·30
	6·60	65
	6·00	35
	5·50	20
	2·35	70
From 8·45 on 8·50	0·00	17 + D
D——	8·50	—— ×
	8·45	Δ
	8·00	20 + D
	7·65	30
	7·06	30
	6·50	22
	5·50	24
	5·10	35
	4·00	77
	2·50	66
	1·10	55
From 12·95 on 13·30	0·20	54 + D
D——	13·30	—— ×
D + 55	13·18	
+ 70	12·95	to B
Δ	4·12	
40	3·60	
35	3·20	
D + 40	2·00	
D + 54	1·12	
D + 20 —	1·00	—— ×

From A on Base Line

DIAGRAM No. 4.

	6·80	△ to 075 on 11·63
	5·00	15 + D
	4·50	10
	3·06	15
	1·80	50 + D
	1·30	55 + D
From 8·55 on 8·60	0·50	50 + D
D——	8·60	— × ——
	8·55	△
	8·44	30 + D
	7·50	40
	5·50	1·20
	3·25	30
	2·00	43
	0·50	30 + D
From 11·30 on 11·63		
	11·63	13
D——	11·50	— ×
	11·30	to B
	9·00	15
	8·30	25
	7·20	22
	6·30	77
	5·00	84
	3·80	85
	2·60	30 + D
	1·66	3 + D
△	0·75	
D——	0·00	— 17 + D
From A on Base Line		

5



6

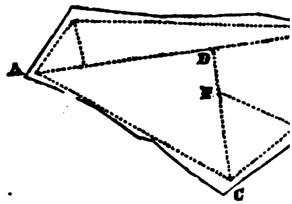


DIAGRAM No. 5.

	3·72	to 6·66 on 7·20
From 4·73 on 10·78		
	3·60	30 to corner
D——	3·36	——×
——	3·08	to A or 0·00 on base line
	0·00	27 + D
From 666 on 7·20		
D——	7·20	——×
	6·84	22+D
Δ	6·66	20+D
—	4·50	36
	2·00	26
From 5·50 on 5·80	1·00	23+D
D——	5·80	—— + ——
—	5·50	30 Δ
	2·30	75
From 10·47 on 10·78	0·20	22 + D
	10·78	45 to corner
D——	10·64	——×
	10·47	to B 40 + D
	7·10	14 + D
	5·60	12 + D
Δ	4·73	24
	3·60	40
	1·20	33
From A on Base Line	0·00	23 + D

DIAGRAM No. 6.

	2·62	to 2·67 on 3·28
From 1·43 on 4·15		
	4·15	to 6·90 on 7·20
Δ	1·43	
From 5·50 on 10·34		
	3·94	28+D
D——	3·90	——×
	3·60	32+D
—|	3·46	to B on AB
	2·50	15
From 2·67 on 3·28	1·00	16 + D
D——	3·28	——×
—|	2·67	Δ40
	1·60	34+D
From 6·90 on 7·20		
D——	7·20	——×
Δ	6·90	50+D
	6·00	42
	4·50	10
|—	2·60	20
	1·70	10
From A on AB	0·00	25+D
Check Line	1·45	to 8·65 on 8·95
From 1·48 on 10·34		
	2·25	25 to corner
D——	2·22	——×
	1·96	to A on Base Line
	1·60	22
From 8·65 on 8·95	1·00	25+D

D——	8·95	—— ×
	8·74	32 + D
△	8·65	△
	5·80	12
	3·00	34
	1·50	17
	1·00	24
From 9·83 on 10·34	0·00	40 + D
	10·34	24 to corner
D——	10·20	—— ×
	9·83	to B
	5·50	△
From A on Base Line	1·48	△

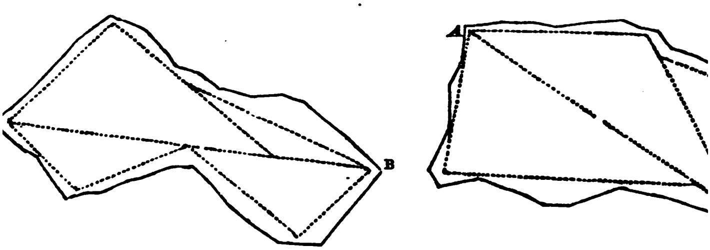


DIAGRAM No. 7.

	3·48	28
D——	3·40	—— ×
	3·25	to B on AB
	3·00	30
	1·50	50
From 455 on 472	0·35	55 + D
D——	4·72	—— ×
	4·55	△
	4·10	40 + D
	2·80	56
	1·30	45
From 3·80 on 3·80	0·55	27 + D

	3·80	to 5·74 on AB
	3·76	63 + D
	3·00	40
	2·00	30
From 306 on 323	1·00	35 + D
D——	3·23	—— ×
	3·06	Δ
	3·00	32 + D
	1·35	10
	0·80	20
From A on AB	0·00	24 + D
	6·40	to 3·57 on 6·80
	5·60	25 + D
	4·60	40
	3·50	87
Check Line	2·75	99
	0·80	50
	0·30	25
	0·00	17 + D
From 1164 on 1200		
D——	4·80	—— ×
	4·60	A on AB
	3·60	20
	3·00	17
	2·00	25
From 660 on 680	1·00	30 + D
D——	6·80	—— ×
	6·76	12 + D
Δ	6·60	Δ
	6·00	36
	5·50	43
	5·00	40
	4·15	30 + D
From 8·50 on 1200	3·57	Δ
D——	12·00	—— ×
	11·64	to B on AB
Δ	8·50	
From A on AB	5·74	Δ

DIAGRAM No. 8.

	8·00	to 8·64 on AB; 90 + D
	7·00	45
	5·44	17
	4·00	75
	3·20	80
From 450 on 494	1·00	16 + D

	4·94	18
D——	4·86	—— ×
	4·50	Δ 5
	3·10	15
	1·85	28
From A on AB	0·5	10 + D

	2·76	to 5·87 on 6·90
	2·30	35
From 234 on 255	1·50	30

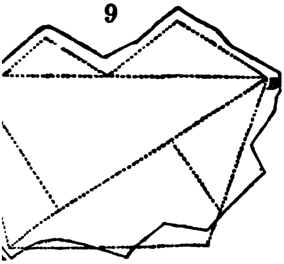
D——	2·55	—— × 15
	2·34	Δ
	1·30	23
From 230 on 690	0·42	40 + D

	5·80	17 to corner
D——	5·76	—— ×
	5·60	to A on Base Line
	3·50	34
	0·90	45
From 652 on 690	0·52	40 + D

D——	6·90	—— ×
	6·62	25
	6·52	Δ 26 + D
	5·87	Δ
	2·30	Δ
	2·22	60
	1·20	60
From 1052 on 1085	0·00	24 + D

D——	10·85	—— × 20 + D
	10·52	to B
	9·00	68 + D
From A on Base Line	8·64	Δ

9



10

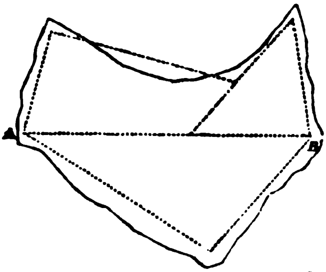


DIAGRAM No. 9.

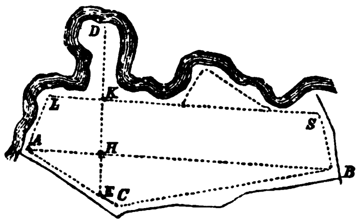
Check Line	2·75	to 1·10 on 5·50
From 6·40		
Check Line	5·33	to 978 on 10·20
From 2·20 on AB		
	5·50	to B on AB
	4·40	42
	3·25	22
	2·60	94
Δ	1·10	20 + D
D——	0·70	—— ×
From 670 on 670		
	6·70	Δ
27	6·50	
60	5·30	
D——	4·40	—— ×
	3·90	33 + D
D——	3·26	—— ×
30	2·00	
D——	0·65	—— ×
From A on AB		
	2·00	to 8·52 on 10·20
	1·90	30
	1·00	23 + D
From 2·30 on 2·52		

D——	2·52	—— ×
	2·36	27
	2.30	Δ
From 285 on 285	1·00	36 + D
	2·85	to 5·05 on 10·20
	2·50	35
	1·00	22 + D
From 335 on 360		
D——	3·60	—— ×
	3·56	22
	3·35	Δ
	3·00	38
	2·20	35
	1·60	20
From B on base line	1·00	15 + D
D——	5·84	—— × 15
	5·60	to A on Base Line
	5·00	72
	4·00	83
	3·40	78
	2·50	80
	1·60	90
From 9·78 on 10·20	0·70	20 + D
	10·20	24
D——	10·10	—— ×
	9·78	Δ
	9·50	15 + D
	8·52	Δ
From 10·00 on 10·40	5·05	Δ
10	10·40	
D——	10·30	—— ×
	10·00	to B
	6·40	Δ
Δ	2·20	
From A on Base Line		

DIAGRAM No. 10.

D——	5·20	—— ×
	4·80	42
	4·72	B on AB
	3·50	23
	3·20	30
	2·50	15
From 700 on 730	0·30	33 + D
D——	7·30	—— ×
	7·00	△ 37
	6·00	47
	5·00	68
	2·50	45
From A on AB	1·00	10 + D
D——	3·50	—— ×
	3·30	to A on base line
	2·00	45
From 595 on 628	1·00	32 + D
D——	6·28	—— ×
	6·17	48
	5·95	△
D——	4·60	—— ×
35	3·70	
45	2·10	
D——	0·90	—— ×
From 2·70 on 5·03		
	5·03	to 512 on 940
	2·70	△
	2·50	48
From 380 on 413	1·00	18 + D
	4·13	14 + D
D——	4·08	—— ×
	3·80	△
	3·40	22
	2·50	15
	1·65	26
From 904 on 940	1·30	20 × D
D——	9·40	—— ×
	9·04	to B on base line
△	5·12	
From A on base line		

11



12

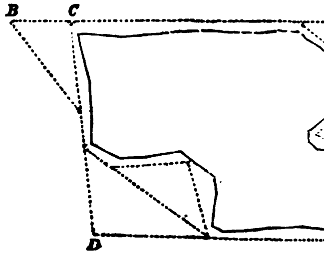


DIAGRAM No. 11.

	5·55	
Ri		ver
	5·45	
55	5·44	
77	5·27	52
80	5·00	60
40	4·50	58
43	4·00	40
R + 38	3·65	36 + R
	2·94	to 6·85 on 8·96
	1·18	to 2·30 on AB
From 2·72 on 3·65		
	1·40	to 4·37 on 8·96
	1·20	23 + R
	0·80	15
From 2·40 on 267	0·30	30 + R
R ——	2·67	—— ×
	2·40	△
	1·75	36 + R
	1·25	20
	1·00	20
	0·60	44
From 1·60 on 8·96	0·20	20 + River

D——	7·05	—— ×
	6·90	to B on AB 17
	5·80	35
	4·70	30
	3·30	65
	2·10	27
From 3·26 on 3·65	0·50	22 + D

D——	3·65	—— ×
	3·45	26
	3·26	Δ
Δ	2·72	
	2·45	26
	1·00	14 + D
From A on AB		

D——	2·00	——	
	1·95	to A	
	1·80	18	RIVER
	1·30	20	
	0·90	10	
From 8·60 on 8·96	0·50	12	

R══	8·96	══ ×
	8·80	30 + R
	8·60	Δ
	8·50	43 + R
	7·50	25 + R
	6·85	Δ } discontinued
	6·20	45 + R
	5.50	44
	5·20	20
	4·85	0 + R
	4·37	Δ offsets resumed
	1·60	Δ offsets discontinued
	1·35	5 + R
	0·80	40
From 1·80 on 2·50	0·40	73 + R

R——	2·50	—— ×
	2·20	10 + D
	1·80	△
	1·75	33
	0·60	24 + D
From 9·70 on 9·84		

D——	9·84	—— ×
	9·70	to B
From A on Base Line	2·30	△

DIAGRAM No. 12.

	2·42	to 0·90 on 4·72
	2·03	20 + W
	1·00	18
From 2·48 on 2·65	0·25	25 + W

D——	2·65	—— ×
	2·48	△
	1·80	70
	1·50	70
	1·00	52
From 4·72 on 4·72	0·32	25 + W

	4·72	to 3·57 on 9·10
△	0·90	
	0·50	
From 4·10 on 6·70		

	3·55	to 2·85 on 6·70
From △ B on AB		

	2·08	to 2·50 on 6·92
	2·00	30
	0·94	10
From 2·10 on 2·33	0·25	30 + W

	2·33	
	2·15	20
	2·10	Δ
	1·00	20 + W
From 4·55 on 6·92		

Check Line	2·76	to 5·28 on 6·92
	2·47	25
	2·00	20
	1·00	24 + W
From 2·16 on AB		

	6·92	to A on Base Line
W + 42 Δ	5·28	
40	4·60	
discontinued { Δ	4·55	
Δ	2·50	
17	2·23	
W + 20	1·00	
From 9·10 on 9·10		

	9·10	Δ
W + 25	8·90	
27	8·00	
Wood 45	6·50	
26	4·10	
W + 40	3·70	
Δ	3·57	
From 6·70 on 6·70		

	6·70	Δ
Δ	4·10	
W + 24	3·87	
30	3·00	
	2·85	Δ
35	2·00	
W + 20	1·00	
From 9·40 on 11·25		
	11·25	B on Base Line
Δ	9·40	
W + 32	9·23	
30	9·00	
2	8·00	
40	7·00	
37	6·50	
17	5·60	
26	5·00	
30	4·00	
Wood + 24	2·20	
Δ	2·16	
From A on AB		

The Areas of these Fields are as follow:—

	A.	R.	P.		A.	R.	P.		A.	R.	P.
No. 1	5	1	35	No. 5	3	3	35	No. 9	6	1	37
No. 2	6	1	28	No. 6	3	1	24	No. 10	4	1	36
No. 3	6	3	29	No. 7	4	0	25	No. 11	3	1	23
No. 4	3	3	24	No. 8	4	2	20	No. 12	4	0	36

A few Explanatory Remarks are Annexed, which may be useful to the Beginner.

DIAGRAM. No. 1—Has merely a common base AB, and two triangles. No. 2 has also these, and in addition two check lines. No. 3 has the base AB, and a triangle upon it, on the one side; and a triangle upon a portion only of the other. No. 4 is very simple. No. 5 differs from any of the preceding. In taking the measurements in the field, the lines AB, BC, CD, and DA, are measured in succession all round, DE being taken last; this is done to save going over the ground twice, but in plotting it, the reverse must be adopted:—Draw AB, marking off the △ E 4·73 chs. upon AE, construct the triangle ADE, AD, being 3·08 chs., and DE 3·72 chs.; then the point D becomes fixed in relation to B; from D, as a centre, at the distance DC, 6·66 describe an arc, and from B, at the distance BC, 5·50 describe another arc, and from C, their point of intersection, join CD, CB.

No. 6 has a base AB, and a simple triangle upon its left side. On the right side, upon AD, a portion of the base, construct the triangle ACD, from C; at the distance 2·67 (CE) describe an arc, and from B, at the distance 3·46 (BE) describe another; join CE and EB: EF 2·62 chs. is a check line.

No. 7 has a base AB, with a triangle upon part of it, on one side, and a check line from the triangle to the point B, required for taking offsets to the hedge, and having two smaller triangles upon the other side of the base line. No. 8 has a *base line AB, with* a triangle upon each side, and a

smaller triangle to get the hedge, upon the side of one of these triangles.

No. 9 has a base line AB, having a large triangle upon each side of it, and two smaller triangles based upon one of them. No. 10 is nearly similar, except that the second triangle upon one side has one of its sides commencing from the point A, and the other side from a point in one of the sides of the first triangle. No. 11 is the survey of a field bounded by an irregular river. The arrangement of this is more complicated, and may therefore require a special description; it is a plan generally and necessarily adopted.

AB is the base line, upon AB is constructed the triangle ABC; then, from a given point (E) in the side AC, a line ED is drawn, running through a given point H in the base and prdduced to D; the line ED running in the centre of the bend, and offsets taken from it to the river. From A and K, as centres, are described arcs intersecting at L, and AL and KL being joined, LK is then produced to S, and SB measured as a check line and for the offsets of the adjoining hedge. Upon a portion of KS is constructed a small triangle within the bend, so as to be within offset distance to the river. The following are the lengths of these lines as obtained from the field notes, arranged in their order for plotting. AH, 2·30; AB, 9·70; AE, 2·72; AC, 3·26; CB, 6·90; EH must be joined and produced to the river. EH is 1·18; EK, 2·94; AL, 1·95; LK, 1·75; KS, 6·85, and BS, 1·80. The sides of the small triangle are 2·40 and 1·40. In surveying the field, it will be found that the first line chained was AB, then from B, turning to the left, a circuit was made of the field back again to B, the small triangle was then taken, and last of

all was measured the line EHKD, which tied the whole in; great saving of time and distance was thus effected.

No 12 is the survey of a wood obtained by the measuring of the supplemental angles. The base line AB was measured along the side of the wood, the distance AC being taken (9·40) and the whole distance AB being 11·25; from C the line CD was measured 6·70 chains, and upon it were taken the △s 2·85 and 4·10; from B, a line (3·55) was subsequently measured to 2·85; this line measured the angle BCD, which is the supplemental angle in that corner of the wood, and therefore determined the direction of the line CD in relation to CA. From D, the line DE (9·10) was measured, having upon it the station 3·57; to this station a line 4·72 was subsequently taken from the former station 4·10 upon the line CD; this line 4·72 measures the angle CDE, and therefore determines the position DE. Upon this line also is based the smaller triangle whose sides are 2·48 and 2·42; E was now joined to A, and being measured, acted as a check line upon the previous work, it was found to be 6·92 chs. long. Upon this line also there was a small triangle whose sides are 2·10 and 2·08 turned inwards to get the wood. The angle CAE was also measured as another check, by the line 2·76 which begins at 2·16 on the base line, and runs to 5·28 on 6·92.

Had this example been an open field instead of a wood, a very different plan would have been adopted, as a base line would have been run *within* the property, and through the whole length of it, and triangles based upon this, to the several corners. Now, the base line is necessarily without, and the only method that can be adopted is that of drawing lines all round it, and measuring their inclinations by

producing one of the sides at each corner, and measuring the supplemental angle, as at C. At the corner D, where the wood makes a re-entering angle, as the angle CDE itself *can be* measured, there is no occasion to produce one of the sides outwards and to measure the supplemental angle. This is also the case at the angle at A. The angle at E need not be measured; ED is fixed in relation to DE, and CA is also fixed in relation to DC, therefore they are fixed in relation to each other; both angles being therefore known, the measurement of one of them is a sufficient check.

Where the woods are large, this is however a tedious plan, and might be advantageously superseded by the use of the CIRCUMFERENTOR, which is especially adapted for practice of this kind.

The use and application of this instrument will be found fully explained in the author's larger work.*

CHAP. VI.

SURVEY OF FIELDS NEAR MAIDEN LANE.

PLATE No. 2 is a plan of the point of junction of Maiden Lane with the Junction Holloway Road, and of six or seven fields in one of the corners.

The extent of the survey was settled in the first instance, and the whole of the ground carefully examined, and the arrangement of the lines, as much as circumstances might afterwards allow, predetermined.

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* Castle's "Engineering Field Notes." Simpkin and Co., Stationer's Hall *Court*.

The lines are numbered in the Notes and on the Plan, n the order that they are used for the plotting.

FIELD NOTES OF SURVEY.

	6·34	to 16·61 on 1728
	6·33	15 + p + 21 + 15
		D
	5·95	6 + p + 9 + 16
		D
	5·44	30 + 15
p —	5·38	— +
p + 5	4·90	28 to end of fence
	4·51	12 + waterfall
p + 10	4·38	8 + fence + D
	4·23	6 + 20
D—	4·22	— + + D
D		D
13	4·16	20
D—	4·10	— +
D—	4·00	— +
D		
3	3·90	
	3·26	20 + 15
p + 5	2·97	20 + 20
path + 10	2·00	30 + 15
	1·23	33 + 20
		D
	0·94	28 + 15 to paling
path + 9	0·70	
From 544 on 609		

	3·54	to 583 on 609
	3·27	3
	2·62	10 to paling
	2·50	10 + fence + 8
	2·39	58 + 26 to G.P.
	2·09	88 to G.P.
	1·93	23 + 18
	1·68	4+p+22 + fence + 6
path —	1·65	— × 5 + path
From 860 on 1067	1·00	9 + 10 + 3 to paling

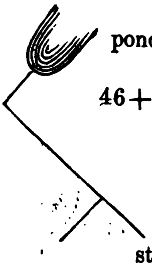
paling —	6·09	— × 13
D—	5·95	×
	5·90	2 + 18
	5·83	Δ
	5·80	1 + D
Δ	5·44	
path	5·39	— ×
	5·00	2 + D
	4·48	to 487 on 10·67
	4·47	0 + D
pond —	0·61	— pond
13	0·60	33
pond —	0·31	— pond
pond		
12 + 4	0.30	
From 578 on 734		

	5·19	to off 23 at 8·20 on 19·55 (page 86)
4	5·70	
8	5·00	
+ 2	1·55	
D + 6	0·00	
From 591 on 734		

	5·99	to 483 on 968
	5·44	2 + D
	2·96	8 to G.P.
From 734 on 734	2·80	10 to G.P.

Δ	7·34	to 1014 on 1728
	5·91	
	5·85	
Δ	5·78	
	5·75	29 +
	5·60	26 + pond (35)
	5·43	32 + pond (35)
	5·25	40 to G.P.
	3·00	18
	2·10	10
	0·72	4
	0·55	0
	0·25	6
	0·13	12
From 616 on 1306		

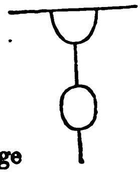
	13·06	to offset 14 at 147 on 1955
10 + 30	13·02	
D		
10 + 76	6·83	
	6·16	
D		
10 + 73	6·02	4 + D
	6·02	
From 1063 on 1067		



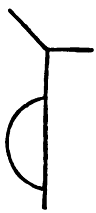
pond		
46 + p + 0	10·67	
	10·63	△
15	10·50	
stile —	10·46	— +
P		P
to paling 10 + 3	9·00	8
path —	8·74	— ×
to paling 10 + 6 △	8·60	
D—	4·87	△ —— ×
From 1443 on 1728		

	9·68	to offset 26 at 16 00 on 19·55
44 + 0	9·35	
haystack + 2	9·05	
46	9·00	
30	8·00	
7	6·00	
△	4·83	
D + 12	4·79	
18	3·00	
0	1·46	
D + 3	1·00	
From 17·28 on 17·28		

		to offset 27 at 710*
		on 12·30 (p. 83)
	5·56	18 + 13
	5·41	32
	3·00	22
	2·70	0 + oval
	2·40	22
	1·00	13 + hedge
From 765 on 1160		
page 83		



△	4·06	to 100 on 1160
	4·05	11 + p + 15
	3·72	27
	3·26	7 +
	2·95	3 + p + 26
	1·18	24
path —	0·93	— ×
From 574 on 577		

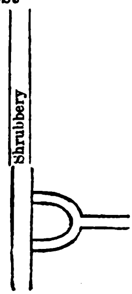


fence —	5·77	— ×
△	5·74	
	5·67	3 + $\overset{\text{D}}{16}$
p —	5·58	— × 22
30 D —	4·50	4 + 16
40 P		
30 D —	4·12	10 + 12 — ×
	3·00	9 + 16
	2·56	30 + 15
	0·95	4 + 20
	0·80	24 + $\overset{\text{D}}{18}$
p —	0·57	— ×

From 765 on 1160	0·20	16 + $\overset{\text{P}}{12}$ + 13 + $\overset{\text{D}}{15}$

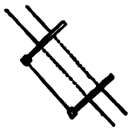
	11·60	to 1728 on 1728
16 + 3	11·56	14 + p
10 + 6	11·00	17 + p
$\overset{\text{D}}{12}$ + 10	10·00	8 + 2 path
+ p —	9·53	— ×
10 + 11 + p + 7	9·00	
10 + 23 + p + 26	7·90	
to post $\overset{\text{D}}{20}$+18+p+25	7·70	
	7·65	△
D —	7·37	— ×
	7·20	27 + D
path + 35	4·00	
path + 21	2·00	
△	1·00	
to post of stile 16	0·76	
stile —	0·69	— ×
to G. P. 31	0·36	
to G. P. 41	0·17	
From 1230 on 12·30		

76	12·30	to lamp post
	12·24	
	11·76	30 + 22
	11·70	4 to pump
	10·92	12 + 20
	10·50	16 + 13
	9·32	20 + 9
H + $\overset{\text{P}}{9}$ + $\overset{\text{R}}{69}$	7·77	
	7·21	25 + 9
	7·10	27



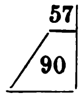
		R grass
	5·00	5 + 30 + D
		R
4 + 15 + 44	3·00	10 + 28 + D
R		R
11 + 35		17 + 20 + D
	1·00	
to G. P. 46	0·58	
11 + 14	0·51	
34 + 12	0·14	
From 1026 on 1026 along High Road		to Kentish Town

to 2 G. P. 0	10·26	to offset 25 at 19·26 on 19·55
to fence 15	9·82	
hedge —	9·73	— ×
	9·64	18 to G. P.
× fence —	9·49	— ×
	9·46	2
	9·34	20
From 1728 on 1728		

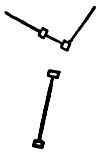


	△	0
	17·28	0 to second brick pier
	17·14	·11 to pier of small bridge.
path —	17·00	— ×
	16·93	8 to further post
	16·86	0 + stile
to tree 0	10·32	
D —	10·31	— ×
	9·08	90 to G. P.
to tree 0	8·39	
D —	8·35	— ×
From offset 14 at 147 on 1955		

	12·58	to A on Base Line
	12·00	20 + D
△	10·16	40 + D
	6·50	76 + D
	2·00	23 + 57
fence —	0·90	— ×
to fence 4 + hedge—	0·70	— ×
from 2166 on 2624—		

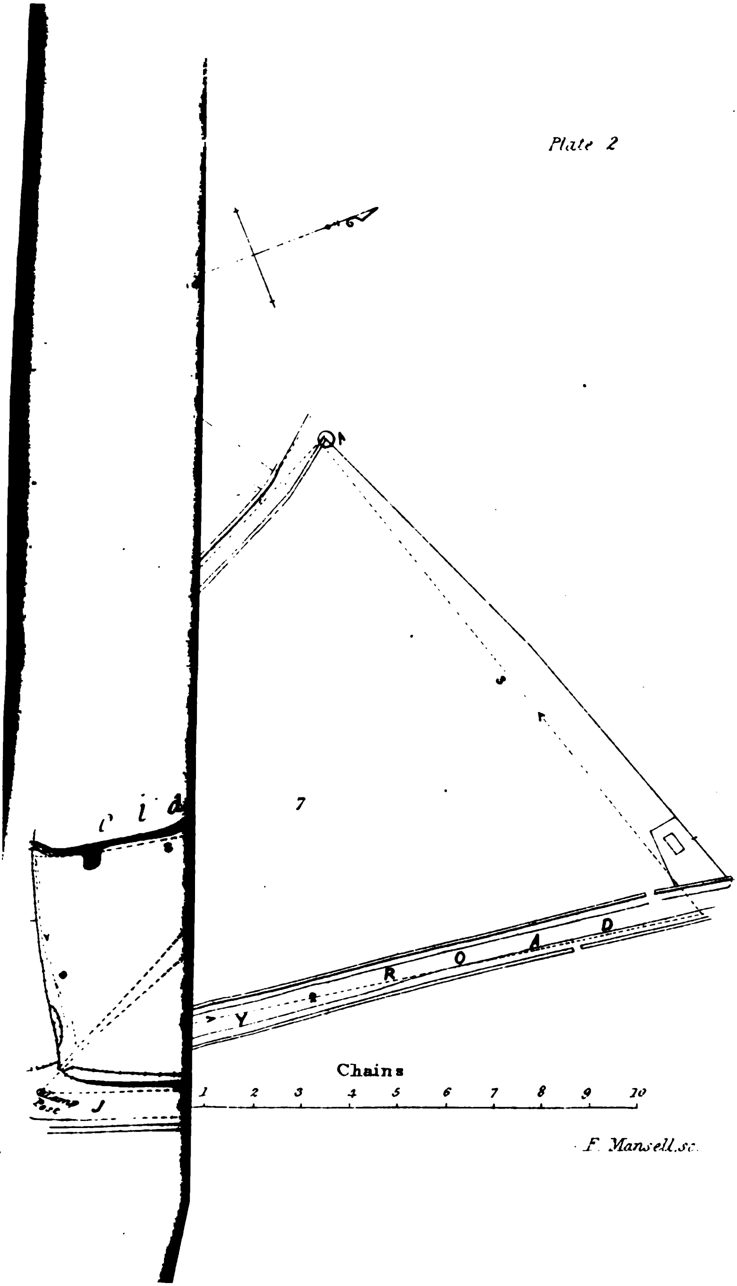


	△	
	26·24	R
15 + 0	25·55	45 + 13
R		R
20 + 16	24·00	25 + 14
R		R
18 + 35	22·52	9 + 15
to G. P. 20 36	22·34	
△	21·66	0 to 9th lamp-post from gate.
R	21·46	14 to on fence
—| D + 20 + 36 + 6	21·27	
to G. P. 20 + 40 + 5	20·62	
	20·00	8 + 5
R	19·08	16 to G. P.
20 + 39	18·93	2 + 13 to G. P.
15 + 40	18·00	2 + 11
12 + 30	15·00	3 + 12 + 5
14 + 10	10·00	29 + 13
12 + 7	8·00	36 + 13
R		R
20 + 6	7·00	36 + 13
15 + 15	500	25 + 10 + D
R		R + P
17 + 20	400	19 + 12 + 10
D + 10 + 26	3·00	10 + 10 + 10 + D
grass R		P
D + 13 + 30 + 3	2·00	10 + 13 D
gate fence —	·82	— × 12 to stile
from B on A. B.		Along the Junction Holloway Road.



	Δ	19·55	0 to B
		19·26	25
		19·15	50
post by hedge	47	19·07	
		19·00	40 + 20
		18·72	37
		18·52	18
to G. P.	30	18·42	
to post	35	17·84	20 to stone
	32	16·00	26 to G, P. Δ
		15·86	15 + 10 G. P.
	26	15·47	24 to fence
	20	14·00	26
		12·24	28 to G. P.
		12·08	26 to G. P.
		8·20	23 to
	31	6·00	
	28	5·00	13
	20	3·00	13
		2·17	Δ
	27	2·00	12
	D + 30	1·70	12 + D
		1·47	14 to Δ on fenc
		1·13	22
	D + 22	1·00	22 + D (20)
	D + 0	0·00	52 + D
	Along From A		Road on Base Line

Plate 2



F. Mansell sc.

CHAP VII.

y carefully referring to the following explanation for very line as he goes on, both as to their arrangement and ne position of the offsets, the learner will find no difficulty hatever in understanding the field notes, and in plotting ne work.

EXPLANATION, &c.

The base line AB, upon which the whole depends, is 9 chains 55 links long. [*Line* 1.]

In the taking of the offsets upon this base line 19·55, reat care is requisite in selecting the most suitable. It ften happens, in practice, that stations for the side triangles *annot be conveniently taken at the base line itself*, but on ffset points near to it, such as a "post in a fence," a "gate ost," the "corners of a fence," or any other "*fixed*" point ear to the line, that *can at any time be referred to;* for nstance, the first station here selected is that of a broad rrow on the fence (offset 14 at 1·47), for the purpose of neasuring the cross hedge.

Observe that this offset should be measured *very carefully.*

The next is that at an offset of 23 at 8·20 chains. The hird station is that of the offset 24, at 15 chains 47 links, ll for the same purpose.

At 16·00, is the common offset of 26 to gate post; at 17·84, 35 on left to a post at the corner of the

1842, 30 to first left hand gate post; at 18·52, 18 links to a post in the corner of the field to the right; at 18·72, 37, on the right, to where a small garden enclosure commences; at 19·00, 40 + 20, *i.e.*, 40 up to the enclosure + 20 to the corner; at 19·07 to stile post on left, by side of hedge; at 19·15, 50 to first right hand turnpike gate post; at 19·26, 25 links to second gate post on right; at 19·55, to the further corner of turnpike house.

From this corner you turn to the left, on the high junction Holloway Road, for a distance of 26 chains 24 links. [*Line* 2.]*

The *direction* of this line is obtained by measuring from the station 21·66, on the line 2624, the line 12 chains 58 links, to A. [*Line* 3.]

The number of the offsets on 26·24, will depend altogether upon the degree of nicety required. At 2·00, on the right, the line is 10 links from the path, and on the left 3 links from the road. Up to 300 there is 10 links of grass on the right between the road and the path; at 400 it ends. On the left, however, the grass continues throughout. At 15 chains, the chain is in the road, having 30 links of road on the left, and 3 links on the right; at 18 chains, it is 10 links to the right of the road, and 2 links to the left of the path, which is 11 links wide. The station selected at 21·66 is a lamp post, being the ninth from the gate. At 26·24 the line ends.

The next line is 12·58 long, and runs from 21·66 to △ A, completing the triangle on the right of Maiden Lane.

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* Only a portion of this line is shown in the plan.

We now return to the Kentish Town side, to the survey of the fields.

From offset 14, at 147 on 1955, turning to the right, a line is measured to the second brick pier of a culvert, being a distance of 17·28; on this there is an offset to a post in the corner of the hedge of the first field, viz., at 9·08, 90 to G. P. [*Line* 4.]

From 17·28 another line is again measured, of 10 chains 26 links, to *second** gate post of turnpike, which was an offset carefully determined upon the line 19·55. [*Line* 5.]

This completes *the first triangle on the left of the base*, which passes obliquely through three or four fields.

Again, from this point 10·26, turning *to the right*, along the same Junction Holloway Road before referred to, but in a *contrary* direction, measure 12 chains 30 links, to a lamp post. [*Line* 6.]

From the end of this line measure 11·60 to the end of 1728, to the second pier of culvert, above referred to. In this line we meet with a path running through the field, the position of which it is necessary to define. *This is the second triangle.* [*Line* 7.]

Upon this line, 11·60, there *is a third triangle based*, for the purpose of obtaining the position of the boundaries of the field; the sides of this triangle are respectively 5 chains 74 links, and 4 chains 6 links.

On this line, 577, the first offset taken is at 57 links, where the path crosses.

At 4·12, ditch crosses—and, from being on the right side of the line, runs 30 links to the left, forming, as the following offset at 4·50 shows, a small pond, whose length on the

* The *line (5) on the* Plan is drawn by mistake to the first post.

line is 31 links, and width 30 links to the left. The offsets, now, go on regularly to the end. [*Line* 8.]

In the next line, 406, which brings us back again, close upon the high road, at the distance of 1·18, there is an offset of 24 to the paling; at 2·95 ($3 + p + 20$), that is, 3 to the path, which is 26 links off from the corner of a small oval enclosure; at 3·26, the offset of 7 links is taken to the widest part of the oval; at 3.72, you come to the end of it, which is 27 links off from the line; the position of the main fence is fixed by the two offsets, 24 and 27, and the beginning and end of the enclosure by their distances on the line; the size of the oval is known by the distance 7. At 4·05 there is an offset of 11 to the path + 15 to the corner of a garden, on the other side of the field. [*Line* 9.]

The offsets are now carried up to where the triangulation was left off. Let us now, therefore, proceed with the triangulation.

The next line we come to is the line 556, which, turning to the right, runs from a *known* point, 765 on 1160, along side of a thick quickset ornamental hedge, to another *known* point, viz., an offset 27 at 710 on 12·30; the line 12·30 running along a sunken road, and the offset 27 at 710 upon it being a post, and having been carefully determined. This line acts as *a check line.* The first offset, at 100, shews the position of the hedge; the second distance, 246, the commencement of an oval enclosure; the next, 270, shews that, at its widest part, it touches the line; at 3·00 the oval ends, and is 22 links off the line. [*Line* 10.]

At 541, another half oval begins, which at its widest part, at the end of the line, is 18 links off, its conjugate *axis being* 13 links. This line completes the Field No. 6.

The next line runs from the brick pier at the corner of No. 5, along the boundary hedge, between Field No. 5, and Fields No. 1 and 4. It is 9·68 chains long, and connects the point 17·28 at the pier, with another known point, at the other end of the field near Maiden Lane, being offset 26 at 16 chains, on the line 19·55. This line finishes Field No. 5. [*Line* 11.]

The following line, 10·46, is a loose line, being one of the two sides of another triangle, based upon a previous line 17·28, and selected for the purpose of surveying Fields Nos. 2, 3, 4. It runs to the corner of Field No. 3. [*Line* 12.]

The other side of the triangle is the line 13·06, which extends from the same stile post to a known point, viz., the offset 14 at 147, on the line 19·55, being the corner, on Maiden Lane, of Field No. 2. [*Line* 13.]

On the line 10·67, there are two stations taken, 487 and 8·60; the object of them will be explained presently. The offsets on this line are the same as usual, except at the end, where they differ somewhat; for example, at 10·46, the line crosses the stile—at 10·50 there is an offset at 15 links, to the angle of the adjoining property. At 10·67 there is an offset to another angle in the fence.

On the line 13·06, the chief thing to be observed is, that at 6·02 the line crosses the ditch between fields Nos. 2 and 3, and that the corner of field No. 2 is (10 + 73) links, to the left of the line, where it crosses, while the corner of field No. 3 is 4 links to the right. The offsets of $\overset{D}{10} + 73$, $\overset{D}{10} + 76$, denote that in this case the hedge is

between the ditch and the line. There is but one △ on this line, viz., 6·16.

The next line measured, 734, is from this △, 6·16 to a previous known point, viz., 1014 on 1728. This line is a check upon the line 10·76, and at the same times it gives the position of the boundary between fields Nos. 3 and 2. [*Line* 14.]

From 734, along the ditch, between 4 and 1, the line 599 measured to a known pond, viz., 483 on 968. This line is a check upon the measured lengths of fields Nos. 1 and 2, as to their sides adjoining Maiden Lane. [*Line* 15.]

Next, from 591 on 734, a line, 579, is measured along the boundary between 1 and 2, to a known point in Maiden Lane, being offset 23 at 8·20 on 19·55. [*Line* 16.]

Then, from 578 on 734, a line is taken between fields 3 and 4, to a previously known point (487 on 1067), and produced to 609 (denoted by the two lines half way across). [*Line* 17.]

Upon this line there is *one* △ on the left (544), selected for the purpose of obtaining the winding of the old Fleet Ditch, that runs at the bottom of the field No. 4, and *another* △ on the right at 5·83, for the corresponding boundary of No 3.

The next line, 354, is a line connecting a point, 860 on 1067, with this last △ 5·83, having offsets to the fence on the right. [*Line* 18.]

And the *last line* is a line measured from the △544 on the line 609 to a known point on the line 1728. This line measures 15·44. [*Line* 19.]

The offsets, on this and the preceeding line, are many,

and somewhat complicated, but certainly intelligible (with a little trouble) to the student, who has made himself master of the preceding explanations.

The Areas of the Fields in the Survey, Plate III., *are respectively as follows :—*

	A.	R.	P.
No. 1 contains .	4.	0.	0.
2 . . .	4.	2.	25.
3 . . .	3.	0.	32.
4 . . .	3.	1.	28.
5 . . .	5.	3.	0.
6 . . .	2.	3.	8.
7 . . .	11.	2.	28.
Total Area .	35.	2.	1.

CHAP. X.

REDUCTION OF CUSTOMARY TO STATUTE MEASURE *and vice versâ.*

The statute length of the perch is 16 and a half feet, but it varies in different counties of England.

In Devonshire and Somersetshire, the customary perch, that is, the local measure of the perch, is *less*, being but 15 feet.

In Cornwall, it is *more*, 18 feet; while in Lancashire, it increases to 21; and in Staffordshire and Cheshire it is as much as 24 feet.

This is a *lineal* difference. There is, also, in some counties of England, a *superficial* difference in the *measure of an acre;* an acre, in Wiltshire, containing 120 square statute perches only, instead of 160.

The Wiltshire customary acre is, therefore, one quarter less than the statute acre, and the rood one quarter less than the statute rood.

As property is frequently bought and sold by the customary measure of the county wherein it lies, the Surveyor is often called upon to reduce it from one to the other.

DIFFERENT VALUES OF THE ACRE.

The number of (statute) square yards in an acre, will of course, vary with the length of the customary perch of the county.—(An acre consisting of ten square chains or of 160 square perches.)

In the statute acre, a square perch is 272·25 square feet, and the acre, therefore, is equal to

$$272{\cdot}25 \times 160 = 43560 \text{ square feet,}$$
$$= 4840 \text{ square yards.}$$

In the acre of Devonshire or Somersetshire, as the square perch contains 15 × 15 square feet, or 225 square feet,

$$\text{the number of sq. feet} = 225 \times 160 = 36000$$
$$\text{and of yards} = 4000$$

In Cornwall, where the perch is 18 feet,

$$18 \times 18 = 324 \times 160 \text{ feet} = 51840 \text{ sq. feet,}$$
$$\text{or } 5760 \text{ sq. yards.}$$

The Lancashire perch is 21 feet long; the square perch, therefore, must contain 21 × 21 = 441 square feet, which will make the acre to contain 70,560 square feet, or 7840 square yards.

The customary acre in Cheshire and Staffordshire is the largest of the whole, each perch being 24 feet; the acre will consist of 24 × 24 × 160 square feet, which is equal to 92160 square feet, or 10240 square yards; while the Wiltshire acre consists only of $\frac{3}{4}$ the statute acre, or 3630 square yards.

To reduce Statute Measure to Customary, or one Customary to another.

Rule 1. Bring the acres, roods, &c., in every case, to square perches; multiply these by the number of square feet in the given perch to bring them into square feet (a foot being the common unit of measurement of both statute and customary measure), and divide by the number of square feet in the required perch. This will bring it into perches; raise these perches to roods and acres and the

result is the area in acres, roods and perches, of the *customary* measure required.

EXAMPLE 1. Reduce 25 acres, 2 roods, 16 perches, statute measure, to the customary measure (Derbyshire) of 15 feet to a perch.

A.	R.	P.	
25.	2.	16	$=$ 4096 statute perches.

but the square feet in a statute perch $= 272\cdot25$;

$\therefore$ $4096 \times 272\cdot25 = 1115136$ square feet.

whence $\dfrac{1115136}{15 \times 15} = \dfrac{1115136}{225} = 4956$ customary perches,

and $\dfrac{4956}{40 \times 4} =$ 30. 3. 36. (A. R. P.)

To bring customary into statute measure, reverse the preceding rule.

EXAMPLE 1. How many statute acres are there in 28 acres, 3 roods, and 15 perches, of Devonshire measure?

A.	R.	P.	
28.	3.	15.	$=$ 28·84375 Devonshire acres

if the Devonshire acre $= 1$; the statute acre $= \cdot826447$

whence $28\cdot84375 \times \cdot826447 = 23\cdot8378$ statute acres,

and $=$ 23. 3. 14. (A. R. P.)

EXAMPLE 2. In 30 acres, 3 roods, 36 perches, Derbyshire measure, how many statute acres?

Answer 25. 2. 16. (A. R. P.)

EXAMPLE 3. A gentleman, wishing to purchase a farm in Lancashire, which is 486 acres and 2 roods, of the *statute* measure, is desirous of knowing how many acres of *customary* measure there are in it.

Answer 300. 1. 14. (A. R. P.)

Example 4. In Cheshire, there is a farm of 240 acres 2 roods, of *statute* measure; a recent purchaser wishes, by the purchase of a portion of the adjoining land to increase his farm to 350 *customary* acres: what will it cost him to do so, at the rate of £40 per *statute* acre? *Answer* £20,000.

Example 5. A nobleman wishing to farm 400 acres of *customary* measure, in the county of Wiltshire, is desirous of knowing what it will cost him, at the rate of £30 per *statute* acre? *Answer* £9,000.

MISCELLANEOUS EXAMPLES.

How many acres of Lancashire measure are there in 250 statute acres?

A. R. P.
Answer 154. 1. 14.

How many statute acres will make up a farm of 300. 2. 30. acres, of Wiltshire customary measure?

A. R. P.
Answer 225. 2. 2.

The base of a triangular field measures 6 chains 25 links of a Cheshire chain, and the perpendicular 4·84. How many acres are there in it?

A. R. P.
Answer 3. 3. 19.

A rectangular field measures, by a Lancashire chain, 12 chains 45 links, and its perpendicular breadth, 8·20 links. How many acres would a farm of the same size contain in the county of Devonshire?

A. R. P.
Answer 20. 0. $1\frac{1}{2}$.

Scotch Measure.

The acre in Scotland consists as in England of 10 square chains (each chain divided into 100 links), and is reckoned in acres, roods, and *falls*, which are equivalent to the English perches; 40 falls making one rood, and 4 roods

one acre. The Scotch chain, however, is 8 feet longer than the English, being 74 feet instead of 66.

The acre being 10 sq. chains $= 10 \times 74^2 = 54760$ sq. feet.

And as 10 sq. chains $= 160$ sq. perches,

$$\frac{54760 \text{ feet}}{160} = \text{one sq. perch};$$

Therefore one sq. perch or fall $= 342{\cdot}25$ sq. feet.

To bring English Statute Measure into Scotch.

Rule 1. Reduce the given area into English perches, and then into square feet by multiplying by 272·25, the number of square feet in an English statute perch; divide this product by the number of square feet (342·25) in a Scotch fall, and you obtain the area in terms of Scotch *falls*, which bring back to their proper quantities in roods and acres.*

EXAMPLE 1. Reduce 32. 3. 25 (A. R. P.) English statute measure, into Scotch measure.

A. R. P.
32. 3. 25 = 5265 sq. perches.

$272{\cdot}25 \times 5265 = 1433396$ sq. ft. in the given area,

$$\frac{1433396}{342{\cdot}25} = 4188 \text{ sq. falls}$$

and $\dfrac{4188}{160} = 26.\ 0.\ 28.$ (A. R. P.)

EXAMPLE 2. Bring 20. 3. 39. (A. R. P.) English, into Scotch measure.

Answer 16. 2. $12\frac{9}{10}$ (A. R. P.)

* *To bring* Scotch measure into English, reverse the preceding rule.

How many Scotch acres are there in 100 English acres, and by how much does the Scotch exceed the English acre?

A. R. P.

Answer 79 2 $7\frac{34}{100}$; by 11200 sq. feet.

The IRISH MEASURE is the same as the Lancashire; the chain is 84 feet long, and the acres are reckoned in acres, roods, and square perches, as in England.

Note.—*In the reduction of statute English to customary, and customary to statute, the same rules must be adopted in this case as in that of English and Scotch measure.*

EXAMPLE 1. How many English *statute* acres are there in 25. 3. 19 Irish acres?

A. R. P.

Answer 41. 3. 24.

EXAMPLE 2. How many Irish acres must be taken to make up a farm of 100 *statute* acres?

A. R. P.

Answer 61. 2. $36\frac{10}{13}$.

EXAMPLE 3. A gentleman has an estate in a rectangular form, $2\frac{1}{2}$ Irish miles one way and $\frac{3}{4}$ the other. How many English *statute* acres are there in it, and what would be the *periphery* in Scotch miles of the same sized estate in Scotland?

Answer 1944 Eng. acres; $7\frac{3}{8}$ Scotch miles.

EXAMPLE 4. There is an Irish farm of 120 acres, and a Scotch one of 150 acres, the former worth £10 per acre the latter £15. For what quantity of land, at £25 per English acre, in the county of Cheshire, could they be exchanged without loss?

A. R. P.

Answer 65. 0. 35.

LAND SURVEYING.

Part the Second.

THE THEODOLITE.

Its Description, &c.

THE Theodolite is the most useful instrument that has been invented, for taking horizontal and vertical angles, as by nature of its construction, it is not necessary that, in the former case, the objects should be in the same horizontal plane; or, in the latter, in the same vertical plane.

This instrument stands upon three legs, and consists of three divisions, and has three motions.

1st.—*The absolute horizontal motion* of the whole instrument moving upon its axis, with clamp-screw (C) to fix it, and tangent-screw T for fine adjustment.

2nd.—*The relative motion* (as to the lower) of the *upper* of the two horizontal circles, to which the vernier (V) is attached, with its clamp screw (C), and adjusting-screw (*t*).

These two motions are for taking horizontal angles.

3rd.—The relative motion of the vertical circle, which has also, as well as the other two, its clamp-screw (C), and fine adjusting-screw (i).

Detail of the first motion, which must be perfectly horizontal.

The lower (K) of the two parallel *Plates* is screwed tightly down to the legs of the instrument. The axis of the whole instrument passes right through to this plate. The centering, at the other end, is fixed to the upper of the two parallel *circles*—the upper one, called the *vernier circle*, from having the vernier attached to it; the lower, the graduated or horizontal limb (L) having its whole circumference graduated into degrees and half degrees. The lower circle has a distinct motion from the upper, working, by means of a collar attached to it, upon the centering of the upper. Upon this is again fixed the collar (D) of the large clamp-screw (belonging to the first division). This collar, as well as the tangent-screw, being attached to the *upper* of the parallel plates, which, connected with a ball, works in the socket of the lower plate, and has a double relative motion.

The upper of the parallel *plates* is made *instrumentally* parallel to the lower graduated circle; and the upper circle (when in correct adjustment) is also parallel to them both. Upon the upper of these circles are two small spirit levels, B, B, at right angles to each other.

By means of two pairs of conjugate screws (P, P), which alter the relative position of the plates, the *upper* one can be always made level, as will be immediately se[illegible]

the two bubbles in the levels being *in the centre* of the tube; and, once set level, the instrument when in adjustment, will be level in any position.

Note.—*By tightening the clamp-collar, and using the tangent-screw, the finest adjustment can be obtained.*

The second motion.—Unclamp the horizontal circle, and the upper will move independently of the lower, or body of the instrument, with which it is connected. This motion of the upper circle, or vernier plate, as well as that of the two (or virtually the motion of the lower), will be perfectly level, if the instrument be correct and in adjustment; and the bubbles, now, as then, will be, in every position, in the centre of the tubes.

The clamp (C), and tangent-screw (*t*) are placed alongside these circles, and have the same office as those of the first motion.

The third motion.—In this, which is a vertical motion, a graduated circle (N) is made to move instrumentally, at right angles with the horizontal plane of the instrument.

This circle moves upon its axis (A), which, passing through the common centre of the instrument, is supported by two shoulders or supports (F, F), at right angles with the vernier plate, to which this axis is made parallel.

This, like the horizontal circle, is graduated to half degrees, and, like that, by means of a vernier (V) supported by the compass box, is capable of being read off to minutes.

Attached to this vertical arc, *above it*, is placed a telescope supported on two Ys or arms in the form of the

letter Y. These Ys, which are tangents to the tube of the telescope, are kept in by clips (*d*, *e*), fastened by a pin.

A long spirit-level (*b*) is fixed to the telescope, beneath and parallel to it.

There is also a compass-box (G), with a magnetic needle. This box is generally placed over the two circular plates, and under the vertical arc. It is useful to find the general position of the north and south points of the estate.

The Working of the Theodolite.

Adjust, first, the parallel screws, (P, P,) so as to have the lengths of the worm as nearly equal as possible above the upper plate.

Extend the three legs, approaching or extending each until the bubbles in the two levels (B, B,) are nearly central, and the plummet, suspended from a hook under the body of the instrument, hangs freely above the centre of the station. The better plan is to move only one leg, which is, of itself, capable of a double motion.

Press the legs firmly in the ground, unclamp the *whole* instrument by means of the large clamp-screw (C), observing to keep the other motions clamped.

It must now be remembered, that the two levels, on the horizontal plate, are conjugate, *i.e.*, at right angles; and, that the opposite screws, also, are conjugate, each pair of them.

Set one level over any two opposite screws: then the other level will be over the other pair.

If both the bubbles of the levels, thus placed, are not in the centre, loosen one of the corresponding conjugate screws, and tighten the other, until the bubble be accurately adjusted. Then loosen and tighten the other pair in the same way, till the same result be obtained. This will probably throw the first out; repeat the process to each, until both bubbles are level.

Having made the plates (*k*, *k*) level, clamp the whole instrument, and, unclamping the parallel circles, set the broad arrow of the vernier, which is in the upper plate, to 360°, or zero, of the larger circle, and clamp it. This must be done by the magnifying glass (*m*), attached to the horizontal circles.

This large circle is divided into 360, and then again subdivided into half degrees, which are numbered from left to right, and, by means of the vernier, read off to minutes.

Again, unclamp the large clamp-screw, and turn the whole instrument towards the left of the stations, between which, you are desirous of taking the angle, until you can cut the object as accurately with the intersection of the cross wires of the telescope, as can be done by the hand. Then clamp the screw (C), and slowly turn the milled-head tangent-screw (T), until you obtain the accuracy you require.

Now, as the zero points of both upper and lower circles are *together* in the present position of the telescope, and as the lower circle is graduated from left to right, *by separating the upper circle, and turning it round*, till the centre of the cross webs of the telescope, which is attached to it, cut *exactly the* centre of the object at the second station, you

obtain the angle between the two, determined by the position of the vernier and the length of the arc of the circle it has described. This can at once be read off from the plate by the broad arrow of the vernier, which will stand exactly above the number of degrees and minutes of the angle, measured between the two given objects.

When the cross webs, therefore, nearly cover the object, clamp the plates as before, and use the tangent screw (*t*); and, with the magnifying glass (*m*), read off the angle, by means of the vernier.

As an additional check, these angles are generally *repeated;* that is, the angle is not taken again, by separating the upper plate and bringing the vernier back to zero, and then taking it a second time—but, without detaching the two plates after the last observation, turning the whole instrument bodily round to the *first* station, and, then unclamping the vernier plate, and turning it round to the *second* station.

The angle read off at this *second* reading, if correct, will be *double* the first angle.

To get the third reading, keep the two plates still together, and turn the whole round, repeating the process as before.

The angle read off at this *third* reading, if correctly done, will be *three* times the angle required.

It is requisite that the verniers should be separately marked, as A, B.

TO TAKE A VERTICAL ANGLE, OR AN ANGLE OF ELEVATION OR DEPRESSION.

First set the whole instrument level, as was explained *before, by* means of the bubbles on the vernier plate. The

bring the bubble of the telescope level (b) to the centre of the tube, observing whether, at the same time, the zero point of the vertical arc coincides with the zero of the vernier. This must be carefully examined by the magnifying glass.

If the instrument is found to be perfectly level, when the zero point of the circle and the broad arrow are together (it is then in adjustment), raise or depress the telescope till you distinctly cut the required object with the horizontal wire, or the common intersection of the three wires. The changed relative position of the broad arrow, will give the required angle, which will be an angle of depression, if the broad arrow be found between the zero of the plate and the object-glass of the telescope; and of elevation, if beyond them.

Note.—The adjustments are not inserted here, as no pupil could understand them without assistance from a master. *They will find them fully detailed in my larger work, on surveying and levelling.*

Parallax is the indistinctness of the cross wires (or spider's-web), occasioned by the point of their intersection not being at once in the common focus of the eye-glass and object-glass.

To correct this error, first adjust the eye-glass, by means of the moveable eye-piece, till you can perceive the cross wire clearly defined, and sharply marked against any white object.

Then, by moving the milled-head screw (M), at the object-end of the telescope, until you obtain the proper *focus, to* suit the distance of the object, you are enabled to

see at once the object, and the intersection of the wires, clearly and sharply defined before it.

THE VERNIER.

The vernier is a contrivance for subdividing, to any extent, the smallest division in a graduated scale.

In the theodolite the lower circle is divided into half degrees or 30 minutes; and the vernier so arranged as to read off to one minute.

On inspection of the theodolite, it will be found that the degrees are marked with a longer line than the half degrees. Should the broad arrow of the vernier fall within any one of these half degrees, then it becomes necessary to measure this quantity, which, by means of the vernier, can be done to one minute.

Hence to *ascertain the number of degrees and minutes* contained in a given angle, observe where the broad arrow of the vernier is; if, between a full degree and a half degree, so many degrees and as many minutes, as are denoted by the number of the first division line of the vernier (reading *onwards* as the degrees number), that coincides with the corresponding division in the limb; or, if between a half degree and a whole one, so many degrees and 30 minutes, *plus* the same number of broken minutes, as is denoted by the *coincidence* of the corresponding lines of the vernier and limb.

Thus, if the broad arrow of the vernier point between 265° and 265° 30′, look along the vernier from right to left till you find a line on the vernier coinciding with, or as it were, forming one line with one of the graduated divisions of the circle underneath—suppose this line to be 10′ from the

broad arrow—the angle will then be 265° 10′; suppose it 20′, and the angle will be 265° 20′, and so on.

CHAP. II.

THE METHOD OF USING THE THEODOLITE.

There are two methods of using this instrument generally adopted; the first by the *needle:* the second by the *back angle.*

The first (*by the needle*) I will briefly describe.—The broad arrow of the vernier, and the zero point of the horizontal limb, are, by means of the adjusting-screw made carefully to coincide, *always with the magnifying glass;* the needle is then released, and allowed freely to play upon its agate; and the whole instrument, with the two circles, firmly clasped together, turned round until the north end of the needle coincides, *as nearly as the eye can tell,* to the north point or zero *in the graduated circle in the compass box.* The whole is then clamped, and if in clamping any error has arisen, it is carefully corrected by the large adjusting-screw (T). Now, if the two plates be detached, and the vernier plate turned round to the object, the angle read by the vernier, will be the angle made at the station, between the first object and the north end of the *needle.*

If the vernier plate be again unclamped, and turned round to the second object, the vernier will, in this case, also denote the angle made between this second station and the same north point.

The second method, by the back angle.—In this case the instrument is placed at the second station, the bearing between the first and second being assumed as a base line, determined in position, and the angles are all based upon that line; thus, supposing the starting-point to be A, the first station B, the base line AB, and the several stations C, D, E, F, &c., then the angle at B is that between A and C; the angle at C, that between B and D, and so on.

THE PURPOSES FOR WHICH IT IS USED.

There are two cases in which the theodolite is found invaluable, and to which it is principally confined.

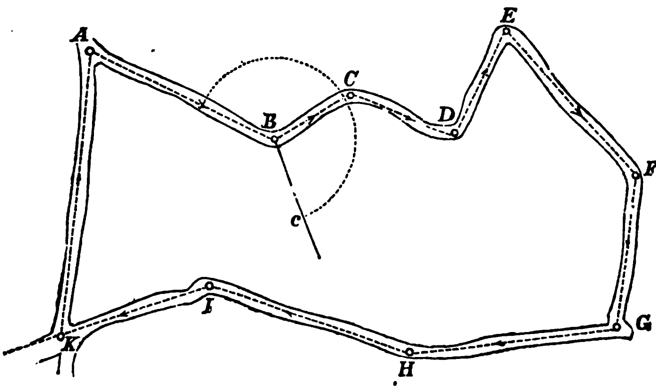
First.—That of the survey of a road or river, by measuring along it, and taking the angles of its several bends, which is called *traversing.*

Secondly.—By determining the position of several new points, in relation to the position of some known line, by means of the angles made between these new points and the old ones. This is called surveying by "*two stations.*"

First Application.

TRAVERSING A ROAD.

The following are the Field Notes of a Road Traverse:—



Check angle between △ K At △ A	291°20′	and △ B.
92	23·15	to △ A on Base Line
50	21·83	80
40	21·00	77
40	17·20	82
60	9·50	80
67	2·00	14
	0·55	50
50	0·30	
Between △ I At △ K	289° 0′	and △ A

H —	15·25	— ×
85	14·00	
	13·60	54
	13·00	to △ K
	12·40	45
90	12·00	
82	11·40	20
50	10·00	32
35	5·00	63
42	1·00	80
Between △ H	146°55′	and △ K
At △ I		

62	16·80	to △ I, 57 + H
48	16·00	60
74	10·80	30
27	4·30	65
42	1·00	70
Between △ G	204°00′	and △ I.
At △ H		

H + 26	17·84	to △ H 70 + H
82	13·50	27
66	9·00	50
55	2·50	34
	0·50	87
67	0·00	
Between △ F	258°20′	and △ H
At △ G		

	13·10	to △ G
	12·60	94
95	12·35	
50	11·00	75
70	6·60	25
50	4·50	36
65	1·00	45
Between △ E	227°50′	and △ G
At △ F		

	16·72	to △ F
44	16·50	70
65	13·00	45
50	8·40	64
92	2·60	30
90	1·15	50
50	0·00	
Between △ D	296°30′	and △ F
At △ E		

40	9·85	to △ E
50	8·75	75
54	8·00	50
26	3·80	70
30	1·00	66
Between △ C	91° 0′	and △ E
At △ D		
	9·70	△ to △ D 22 H
70	9·00	50 + H
10	6·75	90
80	2·30	15
H + 70	1·00	35 + H
Between △ B	231°30′	and △ D
At △ C		
H + 27	7·35	to △ C 80 + H
36	7·00	60
55	5·50	30
Hedge + 40	1·00	75 + Hedge
Between △ A	123°40′	and △ C
At △ B		
H + 82	17·40	to △ B 60 + H
60	17·00	65
30	15·40	82
70	7·20	32
44	4·80	54
From A 50	1·30	52
Base		Line

Explanatory Remarks, &c.

AB is taken as the base line of the survey: it is 17·40 chains long. At B the first angle ABC is then taken, 123° 40′:—This angle gives the direction of the next line BC. Now, in taking the angle ABC, it must be carefully remembered, that BC is a new line, and AB an old one; the latter already known, both on the ground and on the paper; the former depending for its direction upon the *number* of degrees contained in the angle, ABC.

In taking this angle, the theodolite being set at B,

the whole instrument, with the two zeros together, is turned round to A, and then clamped; the upper plate is then released and turned round to C. Standing at B, therefore, and looking towards it, the angle thus read, will, from the direction in which the lower limb of the theodolite is graduated, viz., from left to right, be always reckoned, if it be on the side where BC is now found to be, less than 180°; if it be on the other side, as B*c*, greater than 180°. The angles ABC, AB*c*, are equal; but the line BC, being in the one case, in the second quadrant, makes the angle 123° 40′; whereas, the line B*c* being in the third quadrant, makes the other angle, as read by the instrument, to be 236° 20′. Had the road run in the direction of B*c*, instead of BC, and the angle AB*c* been put down in the book as 123° 40′, it would have been necessary to have added "*to the right.*" This is the plan adopted by some persons; but in the hurry of field work, this mark ⌒ is oftentimes omitted and the direction of the new line, whether to the left, or to the right, becomes a matter of doubt; the work cannot be plotted, and the angles have to be taken again. The method I have adopted guards against every chance of such an error.

In taking any angle, set your instrument first to the end of the old known line; and when it is turned to the new, the angles, read off it, will always tell whether the new line is on the left, or on the right of the old line, looking in the direction towards which the latter was measured; if the angle is less than 180°, it will be on the left, if more than 180°, on the right.

In the present case the angle ABC is 123° 40′; it is less than 180°, and therefore the direction of the new station is

to the left of the old line. To plot this, therefore, draw any line, AB, upon paper, of the required length, 17·40 chs., place your protractor at B, having the bottom edge close against BA, and from the A end, count off 123°½ to the right; mark this off (C), and join BC, then measure BC, 7·35 chs.

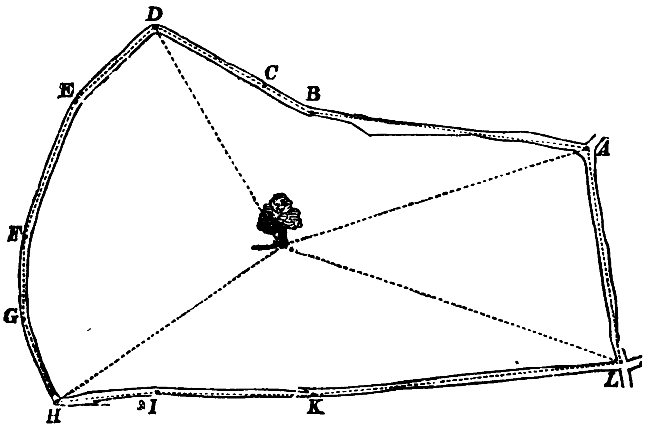
At C, on reference to the Field Notes, you will find the next angle, BCD, is 231° 30′. The new line, CD, therefore, turns to the right, and is in the third quadrant. Place your protractor at C, having the right side of the under edge close against CB; and from B, lay off to the left, the angle (360° — 231° 30′), or 128° 30′. (Should the protractor, however, be a circular, instead of an ivory oblong one, the instrumental angle 231° 31′ can be read off on its right direction at once.) This will give you the angle BCD, and the direction of the next line CD, which is 9·70 chs. long. At D the next angle is 91°, and therefore turns to the left; the protractor must be placed with its centre at D, and the lower edge close against CD; and the angle 91° marked off from the left to the right; this gives DE, which is 9·85 chs. long. The next angle is 296° 30′, and turns to the right; it must, therefore, be subtracted from 360°, and the remainder 63° 30′ must be laid off on the right of DE, giving the new line EF, 16·72 chs. The following angles are all greater than 180°, and therefore turn always to the right, looking in the direction the preceding line was measured, until you come to I, when the angle is 146° 55′; this must, therefore, be laid off to the left. At K it is 289°, and turns to the right. At A the angle is 291° 20′. This angle is a check angle, as it proves the accuracy of the whole previous work. It must be here observed, that these

angles are the exterior angles of an irregular polygon; and as the sum of all the interior angles are equal to twice as many right angles, as the figure has sides, wanting four; and as the sum of all the exterior, together with all the interior angles, are equal to four times as many right angles as the figure has sides; therefore, all the exterior, that is, all the observed angles added together should amount to four more than twice as many right angles as the figure has sides.

Now, there are in the given figure ten sides, and therefore the sum of the angles should amount to twice 10, plus 4, or 24 right angles, equal to 2160°. This, on adding them together, will be found to be the case. The angles, therefore, may be presumed to be correct.

The taking the sum of the angles is a check upon the *field* work. The proof of the *plotting* being correct, is that of the work closing. No offsets must be put in before the angles are laid off, and the work found to close.

I have annexed the field notes of another example of Road Traverse, for the learner's practice.



Check Between △ L at △ A	106° 40′ 78·15	Angle. and △ B and tree
In Field beyond	18·50	80 + road
Hedge—	17·80	— +
	17·35	to △ A 75 Road.
60	17·02	45 + H
33	16·50	27
30	14·60	28
38	11·00	15
17	9·00	47
24	7·75	30
	5·50	33
37	3·15	12
35	2·25	30
Between △ K	86° 30′	and △ A
at △ L	23° 45′	and tree
Road to corner 10	25·74	40 to corner
	25·13	to △ L.45 to cor. Road.
to corner 17	24·50	
9	22·73	43
11	18·48	
	13·76	35
40	7·00	16
H + 69	1·00	2 + H
Between △ I	171° 49′	and △ L
at △ K		
57	12·00	to △ K. 10 + D
20 + 34	11·90	
20 + 30	10·60	11
20 + 20	2·60	
	1·50	30 + D
Between △ H	199° 39′	and △ K
at △ I		

H + 22	7·93	to △ I 29 + H
45	6·90	
	6·50	10 + H
	6·00	8
2	3·00	55
H + 20	1·00	33
	72·00	and tree
Between △ G	92° 22′	and △ I
at △ H		
55	7·90	2 + H to △ H
44	7·09	6
2	5·00	45
34	1·50	
40	1·00	11
Between △ F	161° 11′	and △ H
at △ G		
H + 40	7·07	5 + H. to △ G
	6·97	12 + H H
	6·65	6 + post + 6
17	5·09	30
25	1·00	20
Between △ E	158° 28′	and △ G
at △ F		
44	11·11	3 to △ F
20	5·00	33
26	1·00	22
Between △ D	157° 50′	and △ F
at △ E		
H + 49	8·80	to △ E. 10 + D
	8·40	8 + D
	5·80	22 + 7 to G. P.
	4·80	20 + 7 to G. P.
37	2·00	37 + D
To fence, 42	1·00	45
	32·30	and tree
Between △ C	104° 6′	and △ E
at △ D		

70	9·79	to △ D. 15 + H
21	9·10	
	9·05	34 to wall
11	8·84	
(12 wide) to stile 17	6·93	
	6·90	20 to Fence
To parish stone 15	6·76	
	6·40	27 to hedge
Between △ B at △ C	180° 22′	and △ D
H + 22	4·47	to △ C. 46 + H
30	2·05	36
45	1·30	20
Between △ A at △ B	201° 3′	and △ C
9	21·88	to △ B. 55 + H
49	18·50	22
120	17·00	5
23	10·00	48
4	8·94	60
14	6·00	54
5	4·60	67
10	2·80	45
to Bend 22	1·00	38 + H
From △ A Base		Line.

There are also given for practice, two examples of the method of taking offsets upon roads.

The same difficulties might occur in chain surveying; but as there are more houses by the sides of roads than in fields, and as most roads are surveyed by the theodolite, these examples are placed here with more propriety than in chain surveying.

The examples are distinct, having no connection one

with the other, and are each but a single line, with sundry offsets upon it.

Thus, in Example 1.—First taking the left-hand offsets, then the right.

At 0·00 the fence is 36 links from the line. At 2·70 chains, the corner of the fence is 50 links off, and the fence runs in 120 links. At 3·30, the ponds begins: it is 60 links from the line. At 470, this pond is 70 links from the line, and 60 links wide. At 5·80, the pond ends, it is at this place 50 links from the line, and 30 links wide; and from the other side of it from the line, there are 70 links to the nearest corner of the fence; the furthest corner is not quite at the same distance from the line as it is at 2·70, it being 150, or 20 links nearer.

All the other offsets on the left are so simple, that they need not be continued. It may here be remarked, that the fence in front of the houses, at 7·30 and 8·80 is a straight fence, and therefore its commencement and ending are alone required: the 7·70 and 8·40 are therefore only put in to shew the divisions between the houses.

On the right, at 2·70, is the fence corner. At 3·30, the line is 30 links from the house, which latter is 30 links, or 20 feet deep, and has a garden behind 120 links, or 80 feet long—the two centre houses are each 60 links, or 40 feet deep.

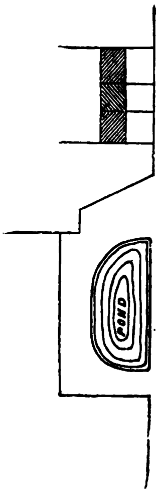
At 14·35 and 14·90, there are two lodges, the front gate to which is 98 links from the line; and the lodges, which are 30 links wide, stand 24 links within the ground. At 21·40, the line is 10 links from the fence on the left, and 60 links on the right; at 21·55, it strikes the fence, and if produced, would cross into the field beyond.

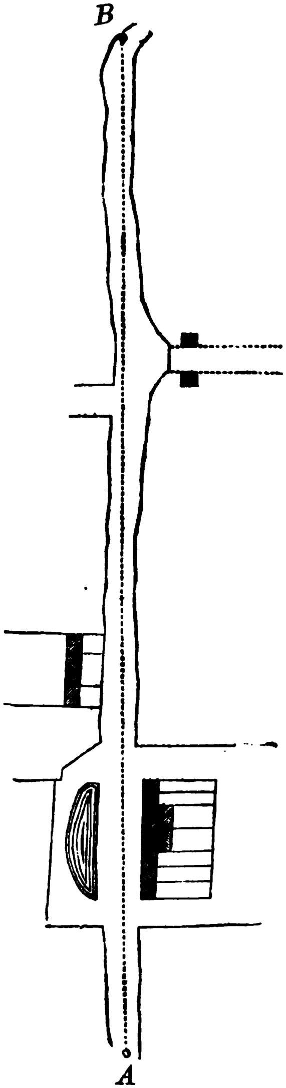
Example 2 is given for the student's practice.

In Wood Block, page 121.

ROAD SURVEYING, No. 1.

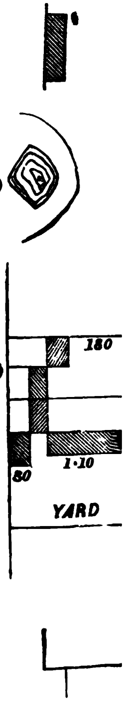
OFFSETS.	CHAINS.	OFFSETS.
Fence	21·55	—— ×
R		R
Fence + 10	21·40	△ B, 60 + Fence
25	21·20	30
40	20·60	20
37	20·00	15
40	18·00	15
37	17·60	33
30	16·00	45
20	14·90	99 + 24 + 30
	14·35	98 + 24 + 30
16	14·10	
Road	14·00	60
20	13·40	
	13·00	55
30	12·00	40
35	10·00	25
30 + 50 + 35	8·80	
	8·40	30
	7·70	
30 + 50 + 45	7·30	
50	6·50	25
150	6·00	
70 + 30 + 50	5·80	42 + 30 + 120
	5·20	39 + 60
60 + 70	4·70	
	4·20	35 + 60
60	3·30	30 + 30 + 120
120 + 50	2·70	30
Fence + 36	0·00	25 + Fence
From A		
BASE		LINE

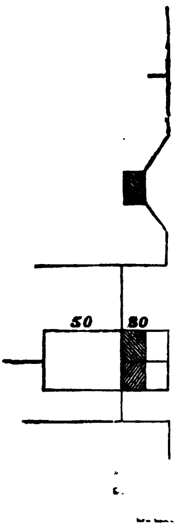


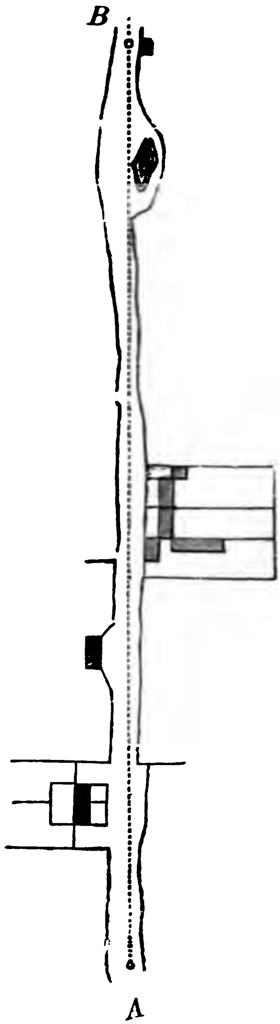

B
A

ROAD SURVEYING, No. 2.

OFFSETS.	CHAINS.	OFFSETS.
	19·60	20 + 30
Fence + 40	19·55	△ B
	19·35	15 + 30
45	19·00	10
60	18·00	30
	17·55	40 + 17
		P
	17·00	10+50+10
70	16·40	15 + 45
65	16·00	40
	15·85	5
37	14·50	16
30	13·00	15
	10·60	35 + 270
	10·35	35+60+30
	9·77	35 + 30
33	9·15	35 + 30
	8·60	
37	8·50	
	8·30	30 + 280
40	7·30	
30+60	7·00	20
30+60	6·30	17
43	5·90	10 + 20
70+46	4·35	
40+46	3·90	20
	3·50	15
40+50	3·00	
70+48	2·55	24 + Fence
+55	0·00	
from A		
Base		Line





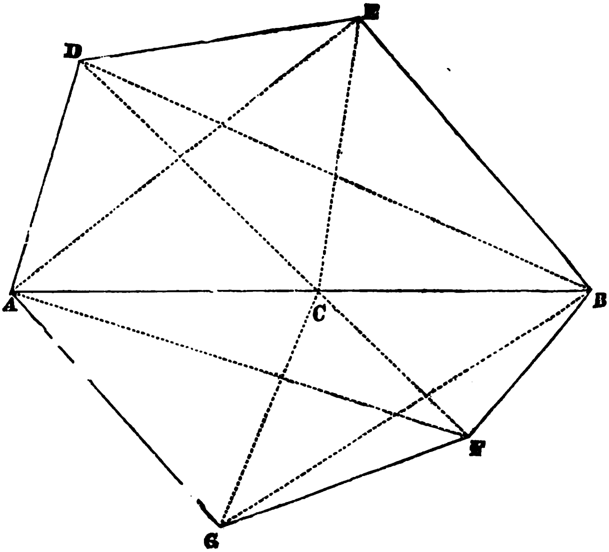

B
A

The Theodolite is sometimes used as a traversing instrument, for the purpose of surveying an irregular field, or impervious wood; though, for the former, if you can get into it, the chain is decidedly preferable; and for the latter, the circumferentor is by far more expeditious and simple.

SECOND APPLICATION OF THE THEODOLITE.

Surveying by Two Stations.

A base line is drawn upon some convenient and level ground; and angles being at either end, taken between this base, and as many new points as may be desired, the relative positions or distances of these points are determined; the lines connecting them forming new base lines for other portions of the survey—thus, as in the following example.—(Page 126.)



The base line, AB, 24·68 is measured, and at A, the several angles between B, and F, G, D, and E, at the one end are taken; and at the other end B, the angles between A and the same points.

By calculation, therefore, or by the protractor, these points can be determined: thus, place your protractor upon AB, having its centre at A, and its left side towards B; and counting from B, lay off the angle BAF 17°. Again place it upon AB, having its centre at B, and its right side, towards A; then reckoning from A, lay off the angle ABF, (360°—311°) or 49°. The intersection of the two lines AF, and BF, will give the point F.

In the same way, by the intersection of AG and BG, the point G can be obtained, and also the points D and E; remembering, that when the observed angles are more than 180°, they must be deducted from 360°, and the remainder plotted from right to left, the observer putting himself in the place of the instrument, and looking along the base line.

The angles taken at C, are merely check angles, as will be clearly seen by the following remarks.

As the point D, is determined by the intersection of the lines AD and DB, without reference to C, the line CD should form a given angle with AB, and if correct, should be found, by the protractor, equal to the observed angle; thus, if the protractor be set against C, the angle ACD should show an angle of 44° 20′, and the angle ACE, an angle of 100° 10′

Example.

Given the base line AB, and the several angles take with it, as shown in the following notes: to determine th lengths of AD, DE, EB, BF, FG, and GA.

Check Angles	292°10′	and △ G
	221°30′	and △ F
	100°10′	and △ E
Between △ A	44°20′	and △ D
at △ C		
	328°30′	and △ G
	311° 0′	and △ F
	48°50′	and △ E
Between △ A	23°40′	and △ D
at △ B		
	322°40′	and △ E
	287°10′	and △ D
	48°20′	and △ G
Between △ B	17°00′	and △ F
at △ A		
	24·68	to △ B
	12·70	to △ C
From △ A		
Base		Line.

Ans. { AD=10 chs.; DE=12 chs.; EB=15 chs.;
BF=790 chs.; FG=11·40 chs.; GA=13·10 chs.

EXAMPLES FOR PRACTICE,

BY TWO STATIONS.

The following examples are given for the learner's practice, who, unless he understand trigonometry, and can from its rules, which is the proper mode, calculate the required distances, must plot them from the notes, and then measure the lengths of AD, DE, &c., by the scale, and compare them with their correct lengths as given below.

No. 1.

	290° 0′	and △ G
CHECK ANGLES.	226°40′	and △ F
	119° 0′	and △ E
Between △ A	49° 5′	and △ D
at △ C		
	333° 0′	and △ G
	315°30′	and △ F
	69°50′	and △ E
Between △ A	26°50′	and △ D
at △ B		
	323°40′	and △ E
	276° 0′	and △ D
	45° 5′	and △ G
Between △ B	21° 0′	and △ F
at △ A		
	29·90	to △ B
	13·87	to △ C
From A		
BASE		LINE.

No. 2.

	297°40′	and △ G
	234° 0′	and △ F
	116°20′	and △ E
Between △ A	52°40′	and △ D
at △ C		
	332°30′	and △ G
	317° 0′	and △ F
	68°20′	and △ E
Between △ A	29°30′	and △ D
at △ B		
	325° 0′	and △ E
	285°40′	and △ D
	47°30′	and △ G
Between △ B	21°10′	and △ F
at △ A		
	35·20	to △ B
	18·00	to △ C
From A		
Base		Line.

Answer to 1st Example:—

AD=14·20 chs.; DE=22 chs.; EB=18·45 chs.; BF=11·70 chs.; FG=11·60 chs.; GA=14·23 chs.

Answer to 2nd Example:—

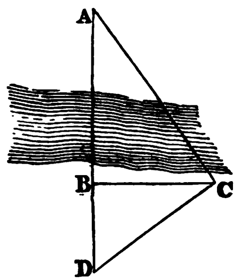
AD=17·70 chs.; DE=27·75 chs.; EB=20·60 chs.; BF=14·10 chs.; FG=13·70 chs.; GA=16·80 chs.

Useful and practical Problems.

PROBLEM I.

To measure a base line across a river.

Let DA be the direction of the line which has been measured up to the river. It is required to ascertain the distance BA at once upon the ground; so as to continue the measurement of the line.



On the line DA, take any point, B, whence a perpendicular, BC, can be taken, which will be free from obstruction, so that BC can be accurately measured; carry the range on across the river, and at A set up a flag; on BC, take any point C, whence A can be seen; and at C erect a perpendicular to AC, intersecting the line AD in D.

Measure DB; then, because ACD is a right angle.

$$\frac{BC^2}{BD} = AB \text{ (Euclid, lib. vi. Prob. 8.)}$$

These angles can either be taken by a cross-staff or by the chain, with the distances of 30 links, 40 links, and 50 links; 50 being the hypothenuse of a right-angled triangle when the base and perpendicular are respectively 30 and 40.

Example 1. Was engaged in the measurement of a base line, that unfortunately crossed a river too wide for the chain—measured up to the river 261 chains 45 links. Sent a man across in a boat, with a flag to carry on the

range, and to plant the flag in the line on the other side. At 261 chains, at right angles with the base line on the right, measured 4 chains 50 links to the water's edge, whence only, on account of the trees near the river's side, the flag was visible.

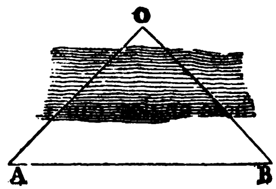
At this point, at right angles with an imaginary line to the flag, measured to a point on the base line, which on trial I found to be 259 chains 25 links: required the width of the river?

Width of river, 11 chains 12 links.

EXAMPLE 2. Measured BC, (B being at the water's edge) 3·85 chs.; found the right angle ACD, to intersect AD, at a distance of 5·00 chs. from B;—what is the length of BA? *Answer* 2·96 chs.

PROBLEM II.

To measure the width of a river with a base line alongside of it.



Take at either end of the base line, with a theodolite, the angle made between the base line and a flag placed at the edge on the other side of the river. Compute the length of the sides by the first of the three cases of trigonometry.

Then AO nat. sine $\angle$ A; or OB nat. sine $\angle$B $=$ the width.

Or construct the triangle AOB by a scale of equal parts, and measure the altitude $=$ the perpendicular width of the river.

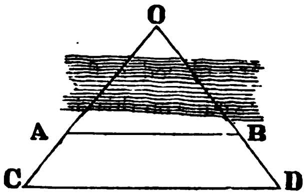
EXAMPLE 1. Took a base line by the side of a river, 12

chains, and observed the angles at its ends to the flag on the other side, found them 25° and 55°: what is the perpendicular width? *Answer* 4·22 chs.

EXAMPLE 2. Given the base 20 chs.; and the angles 44° and 42°; what is the width? *Answer* 9·30 chs.

PROBLEM III.

To find the distance of one object from another, where a river divides them, without using the theodolite.



Let O and A be the given objects, and AO the distance required. From A draw AB at *any* angle to AO, and produce OA to C, measuring AC about one third length of AB; from C measure CD, parallel to AB*; and such that OBD may be in one straight line.

Then, because AB and CD are parallel, the triangles are similar, and therefore CD : AB :: CO : AO;
and CD—AB : AB :: CO—AO, or CA : AO

$$\therefore AO = \frac{AB.CA,}{CD-AB} \text{ the distance required.}$$

If the perpendicular distance be required, we can obtain it, either by similar triangles, CA : AO :: the perpendicular distance between the parallels : to the perpendicular distance across the river.

Or, we can so select the point A, as to have OAC at right

* To make CD parallel to AB: at A and B erect equal perpendiculars which can be done either by a cross staff or by means of the unit proportion of the sides of a right angled triangle: viz. 3, 4, and 5, or any multiples of them whatever.

angles to the river; and AB and CD can then, if necessary, be made perpendicular to it.

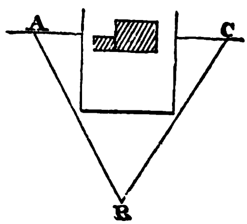
EXAMPLE 1. Took a line, 6 chains, alongside a river, and having had a flag placed on the other side, in the direction I was desirous of going, measured in a range with it from one end of the line, 4·50 chains, then took a second line parallel to the former, 8 chains, to such a point that I covered the flag and the second station of the first line.

What is the width of the river in the required direction? *Answer* 13 chains 50 links.

EXAMPLE 2. Wanted the perpendicular distance across a river: placed a flag on the other side; and from the water's edge on this side, measured 3 chs. back from the river at right angles to it, and in line with the flag: then measured along the side of the river, 8·20 chs. and having set a flag there; ranged from that point, back in a line with the flag beyond the river, until the line from here to the 3 chs. was parallel to the line by the river's side. This line was 10·50 chs. long. *Answer* 10·69 chains.

PROBLEM IV.

To continue the measurement and direction of a given line, when any obstacle stands in the way, which cannot be crossed but can be avoided by going to the right or the left.



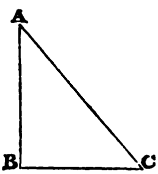
At any point (A), on the given line AC, take an angle with the given line, of 120°, if you would turn to the left, or 240°, if to the right, as in this case, and proceed *measuring* to B, till an angle of

60° made with this line towards the first line AC, will carry you clear of the obstacle.

Take this angle, ABC, 60 degrees, and measure BC the same distance as AB; the point C shall be in the given line and AC shall be equal to AB or BC. By taking an angle of 240 degrees with the line BC, the range of the line can be continued.

PROBLEM V.

To ascertain the height of an object, when the base is accessible.



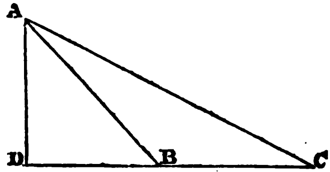
Measure any distance from the base of the object, as nearly equal as possible to the height, and take the angle of elevation by the theodolite.

Let BA be the object; measure BC, and take the angle BCA, then BA is determinable by the case of right-angled triangles.

EXAMPLE 1. What is the height of a tower, whose top, at the distance of 5 chains, 75 links, subtends an angle of 33° 17′? *Answer* 249¼ feet.

EXAMPLE 2. What is the height of a church spire, whose angle of elevation is 6° at the distance of ⅓ of a mile? *Answer* 185 feet.

EXAMPLE 3. Given the angle of elevation 7° 45′, at the distance of ½ a mile; required the height of the object? Answer 359⅛ feet.



If the object be inaccessible, so that DB cannot be measured, range DB on to C, and taking BC, nearly equal to DB: measure BC, and at B and C take the angles of elevation. The angle DBA, being the outward angle, is equal to the angle at C, + the angle BAC, and BC is measured; therefore, the triangle ABC, in the vertical plane, comes under the first case; and AB being thus determined, and the angle ABD, at the base, being known, the triangle ABD is determinable by the case of right-angled triangles, and AD becomes known.

Example 1. Wanted the height of a tower, and the width of a moat around it, when the angle subtended by the top of it, at the edge of the moat was 64° 20′; and at 4 chains 50 links off, was 25° 54′.

Ans. Height of tower 188 ft. And width of moat 90·4 ft.

Example 2. When the angle, at the moat was 45°, and at the distance of 5 chs. was 15°; what was the height?

Answer. 120·8 feet.

Where DB cannot, from any cause, be produced towards C, another plan must be adopted.

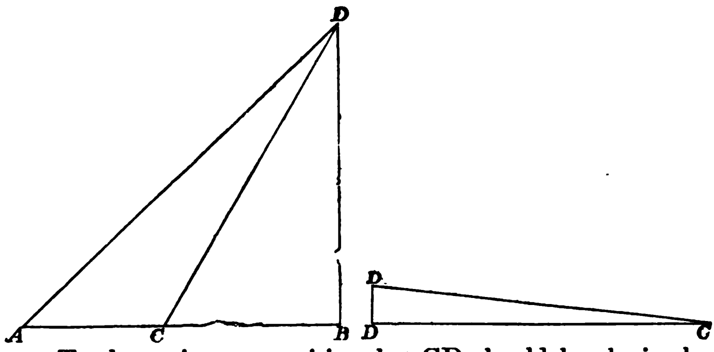
In the last case, because neither AD nor DB could be measured, it was requisite that AB should be made the connecting link between some new triangle, that could be determined; and the given one AB was therefore made a common line to the triangles ABC, and ABD; and being determined by the former, it was the means of determining *the latter.* These triangles are both in the same vertical

plane. *This, however, cannot be done in the case before us, as DB cannot be produced;* we can, therefore, no longer make AB the connecting line. By supposing, however, the horizontal distance DB to be the common intersection of the vertical and horizontal planes, we may be enabled to determine its distance in the horizontal plane, and employ that distance to determine the vertical height AD.

DB comes under the case of Problem II., and AB under that of Problem V., and must be determined in the same way accordingly.

PROBLEM VI.

It was required to find the height above C, of a high tower at D which was inaccessible.



To do so, it was requisite that CD should be obtained, which is the line of intersection of the horizontal and vertical planes.

The base line was first measured, noting the station C. The horizontal angles at A, C, and B, were taken; and at C, the angle of elevation DCD was also found; the height of the instrument was 5 feet.

AB being given, and the angles at A and B, the sides AD, BD are determinable; and AC being given, AC, AD, and the included angle at A, will give the distance CD,* which thus becomes a base for the right-angled triangle, the angle at whose base is the angle of elevation 6° 17′, whence the height can be determined by the case of right-angled triangles.

The base CD was 1206 feet, and the height 133 feet above the instrument; adding, therefore, 5 feet, the height of the instrument, we have 138 feet as the height of the tower, above the point where the observation was taken.

Note.—The distance being under a ¼ of a mile, the correction for curvature and refraction would be inappreciable.

FIELD NOTES.

Offsets.	Chains.	Offsets.
Angle of Elevation at C	6° 17′	to top of tower at D
Between A at C	118° 52′	and D
Between A at B	88° 13′	and D
Between B at A	315° 36′	and D
From A	16·86 7·55	to B to C
Base		Line.

* CD not being assumed to be at right angles.

LAND SURVEYING.

Part the Third.

THE CIRCUMFERENTOR.

THE Circumferentor is the Mariner's Compass, differently divided, and furnished with sights, standing upon one or three legs, and capable of a horizontal motion, by means of the usual parallel plates, or a ball and socket.

The circumferentor consists of a compass box; divided into degrees, and, by means of a vernier, subdivided into three minutes.

It stands upon three legs, and, by means of a pair of parallel plates, is capable of a truly horizontal position, which is determined by a level, placed, so as not to interfere with the reading *under* the compass box.

This compass box, has an absolute horizontal motion round its centering, and is fastened by the clamp screw.

When this is clamped, by detaching the pin which passes through the two plates of the compass box, the brass one,

which, with the vernier attached, works round the inner one, on which are divided the degrees, is capable of a relative motion, and thus partakes of the character of the theodolite; this motion is communicated to it by a rack and pinion.

The instrument, also, has other contrivances; the whole instrument can be turned upon its side, and the spirit level at B, being then in a horizontal position, the instrument is made capable of a vertical motion, reading off to three minutes, by means of the vernier.

DIVISION OF THE CIRCUMFERENTOR.

The line of sights is made the north and south end of the *instrument,* and from each of these the circular rim is graduated toward the east and west points, from 0° to 90°.

On the right of the north of the instrument, looking to the north point of it, should be lettered west, and on the left should be lettered east; and any point between the north and west point of the instrument, read by *the north end of the needle,* is read *north, so many degrees west.*

When the needle is released, and is allowed to play freely, it points toward the magnetic north. The north of the instrument points to the object whose bearing is required, the angle made between these two must necessarily give the relative position of the line of the object, and the magnetic north, and the bearing of the object can thus be obtained by reading off the number of degrees to which the needle points on the graduated circular rim.

Definitions.

A meridian line is a line running due north or south.

The distance of a line is its horizontal measurement.

The angle of bearing of any line, is the angle of bearing made between that line and a meridian line running through the point, where the instrument is placed; and is measured always from north or south, eastward or westward.

Thus a line is said to bear *magnetically* north 16 degrees west, when the needle points to 16 degrees on the graduated circle, and when the direction of the line is to the west of north.

The *reverse bearing* of a line, is merely the bearing taken in a contrary direction.

The reverse bearing of a line, bearing north 38 degrees east, is south 38 degrees west; that of south 75 degrees west, is north 75 degrees east. The reverse bearing, therefore, is measured by the same angle, as the direct bearing, only taken in opposite directions; from south bearing northward, from east westward.

Difference of latitude, or *northing* and *southing,* is the distance that the end of the line is further north or south than the beginning.

The *difference of longitude, or departure,* is the distance that the end of the line is east or west from the beginning.

In changing our position from one point on the earth's surface to another, in a direction making any angle with the meridian, we at once change our latitude and longitude —the one is the northing and southing, the other the easting and westing.

To obtain the latitude and departure geometrically, when the length and bearing of a line are given.

Draw a meridian line through either end, and let fall a perpendicular from the other. This perpendicular is the departure; and that portion of the meridian line intercepted by it, is the difference of latitude.

The *latitude, departure,* and *distance,* form the three sides of a right-angled triangle, whose angle *at the vertex* is the angle of bearing; whose hypothenuse, or radius, is the distance; the latitude, the cosine; and the departure, the sine of the angle of bearing.

The meridian distance of any station, is the distance of that station from the meridian line passing through the first or any other assumed point, and is equal to the difference between the sums of the eastings and westings from that point; and is, east or west, as the eastings or westings predominate.

Examples.

Required the difference of latitude and departure of a line, which bears south 16 degrees 30 minutes, east 3 chains 47 links. *Answer* 3·33 south lat.; 0·98 east dep.

Given a line, bearing north 13 degrees 30 minutes west, and 6 chains 10 links long, to find the latitude and departure. *Answer* 5·93 north lat.; 1·42 west dep.

What are the latitude and departure of a line bearing north 41 degrees 9 minutes east, 4 chains 47 links?
Answer 3·36 north lat.; 2·95 east dep.

A line bears north 22 degrees 45 minutes west, 27 chains 62 links, required its latitude and departure.

Answer 25·47 north lat.; 10·68 west dep.

To find the bearing of a line by the Circumferentor.

Having placed the circumferentor over the station point, release the needle, and then, having unclamped the body of the instrument, by means of the parallel plates, as in the theodolite, make the whole instrument level. Now, turn the whole round until the *north* end of it lies towards the object, and looking through the sight, at the *south* end, fix the instrument, so that the fine web-line, in the north sight, exactly covers the object; then, when the needle has perfectly settled (which should be immediately released on setting the instrument), read off, by the north end of the needle, the number of degrees that it points to, from the north or south division line of the compass-box, according as the north end of the needle is in the north or south semicircle of the instrument; the angle measured by these degrees is called the angle of bearing.

Should the needle not point exactly to any degree, but lie between two of them, turn the instrument carefully, so as to make the needle point exactly to the next lower degree, and, *clamping the whole head of the instrument,* detach, by withdrawing the connecting pin, the two horizontal plates. The instrument having been altered to suit the needle, the flag will be no longer covered by the web. By using the rack and pinion, and carefully bringing the sights back, which are connected with the same plate as the vernier, to cover

the flag, the difference of the angle, in minutes, is denoted by the distance of the broad arrow in the vernier from the 360°, or the zero point of the other plate, which distance, as in the case of the vernier of the theodolite, is read, by observing which line of division in the vernier, reading to the left or the right (as the broad arrow is to the left or the right of the 360°), first coincides with some line in the graduated circle. In the circumferentor, the broad arrow of the vernier is placed in the centre, and if the distance from the 360° exceed half a degree, it is requisite to carry on the observation, as to which line first coincides, all round the plate, so as to end at the 360°. In some circumferentors the vernier is erroneously marked, as, in taking observations, the 15 may become 45, and the 45, 15, they should have been marked $\frac{45}{15}$, and $\frac{15}{45}$, in the same way as in the theodolite, the vernier is marked $\frac{10}{20}$, $\frac{20}{10}$.

CHAP. II.

To find the true bearing of a line, the magnetic bearing and the variation being given.

By the *variation of the compass*, is always meant the variation of the *needle*, which is the *only variable*, east or *west*, from the true north, which is ever constant.

RULE.—*Mark upon paper*, the relative positions of the given line and the *magnetic* north, which represents the north end of the needle, then observe, whether the variation be easterly or westerly; if easterly, the *true* north will be to the left of the magnetic; and if westerly, to the right; place this also on paper in its proper relative position.

The angle made between this last line (of the true north) and the given line, is the angle of bearing; the expression of this angle depending, of course, whether by the variation, it may or may not have been moved into a different quadrant, being often changed from the magnetic N.W. to the true S.W., or N.E.

EXAMPLES.

1. Let the line AB bear N. 24° E., and the variation be 23½° W.; required the true bearing of the line.

AB, bearing N. 24° E., the needle is on the left of the line, but the needle bears west, the true north is on the right of the needle, therefore the line and the true north, being both on the right of the needle, the line being at the greater angle, the difference of the angles is the bearing of the line eastwards, N. 0° 30′ E.

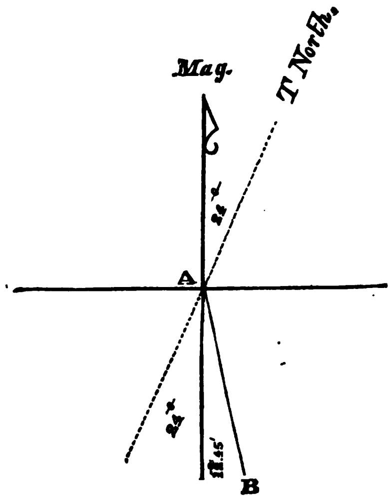
2. Let the reverse bearing of AB be S. 24° W., with the same variation, what is the true bearing?

Ans. S. 0° 30′ W., which is the *reverse* of the former.

3. Let AB bear S. 12° 45′ E., and the variation be 24° W.; required the true bearing?

Now the north end of the needle is to the left of the true north, therefore:—

$$
\begin{array}{r}
24^{\circ} \\
+24^{\circ}\ 45' \\
\hline
= \mathrm{S}\ 36^{\circ}\ 45'\ \mathrm{E}
\end{array}
$$



EXAMPLE 1. Given magnetic bearing AB, S. 34° 20′ E., and variation 3° 27′ W. Required the true bearing.

Ans. S. 37° 47′ E.

EXAMPLE 2. Given AB, N. 74° 15′ E., and variation 12° 45′ W. Required the true bearing.

Ans. N. 61° 30′ E.

EXAMPLE 3. Given AB, N. 11° 30′ W., and variation 13° 20′ E. Required the true bearing. *Ans.* N. 1° 50′ E.

EXAMPLE 4. Given AB, S. 78° 30′ W., and variation 11° 30′ E. Required the true bearing. *Ans.* Due west.

EXAMPLE 5. Given AB, S. 77° 35′ E., and variation 16° 20′ W. Required the true bearing.

Ans. N. 3° 55′ E.

EXAMPLE 6. Given AB, N. 72° 36′ W., and variation 8° 24′ E. Required the true bearing.

Ans. N. 81° 0′ W.

The Bearings of two Lines being given, to determine the angle between them.

RULE. First let both these lines run northwards or southwards. If they run on the same side of north or south, whether eastward or southwards, this angle will be the *difference* of their angles of bearing; if on different sides, it will be their sum.

Next, let one run north and the other south.

If they both run on the same side of the meridian, this angle will be the supplemental angle of the *sum* of the angles of bearing.

If one be on the east, and the other on the west of the meridian, this angle will be the supplemental angle of the *difference* of their angles of bearing.

In the interior angles of a polygon, as an angle may exceed 180°, the required angle might be the difference between the angle calculated as above, and 360°.

EXAMPLE 1. Given AB, N. 16° W., and AC, N. 12° E., to find the angle between them.

$$16^\circ + 12^\circ = 28^\circ = \text{angle between them.}$$

EXAMPLE 2. Given AB, N. 16° W., and AC, S. 12° W., to find the angle between them.

$$\text{Angle} = \text{supplement of sum} = 180^\circ - (16^\circ + 12^\circ) = 152 = \text{angle between them.}$$

EXAMPLE 3. Given AB, N. 84° 20′ W., and AC, S. 49° 51′ E., to find the angle between them.

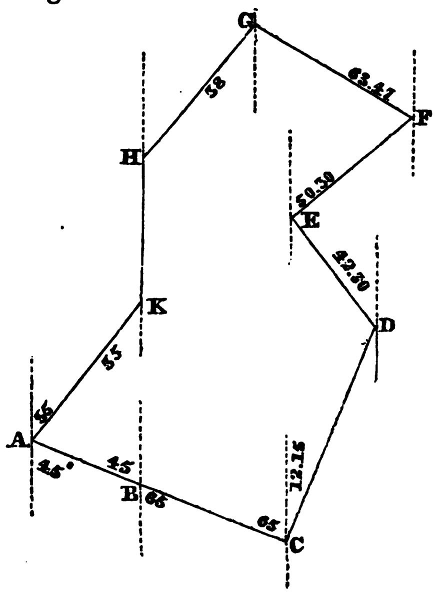
Here the angle = the supplement of their difference.

$$180^\circ - (84^\circ\, 20' - 49^\circ\, 51') = 180^\circ - 34^\circ\, 29' = 145^\circ\, 31' = \text{angle required.}$$

EXAMPLE 4. Given AB, S. 25° E., and AC, S. 16° E.; required the angle between them.

$$\text{Angle} = \textit{their difference} = 25^\circ - 16^\circ = 9^\circ = \text{angle required.}$$

Example. Given a tract of country, with the bearing of its several boundaries, to find the interior angles, AB bears S. 45° E.—BC, S. 65° E.—CD, N. 12° 15′ E.—DE, N. 42° 30′ W.—EF, N. 45° 30′ E.—FG, N. 63° 47′ W. —GH, S. 38° W.—HK, due S., and KA (S. 35° W.) Required each of the angles.



Take first the angle ABC; this is equal to the first angle of bearing, 45° + the supplement of the second angle 65°, that is equal to 45°+115° = 160°.

BCD, the second interior angle, is equal to the second angle of bearing, 65° + the third angle 12° 15′, or 77° 15′.

Thus, ABC being found to be = 160°
and BCD = 77° 15′
CDE = 125° 15′
DEF = 273° 00′
FGH = 65° 43′
FGH = 101° 47′
GHK = 142° 00′
HKA = 215° 00′
KAB = 100° 00′

90 | 1260° 00′
14 right angles.
+ 4
18 equals twice the number of sides of the polygon.

This is, however, no check upon the *field work,* as all the interior angles, right or wrong, will *always* come to twice as many right angles (— 4) as the figure has sides, provided the work be *correctly calculated.*

The only check is the following, depending upon the axiom, that the whole northing or southing of a line, of any bearing, is equal to the sum of the northings or southings of any number of lines of the same bearing, when the sum of the several distances is equal to the one distance of the whole line. Resolve, then, all the bearings and distances into their corresponding northings and southings, and eastings and westings (either by construction, or by finding their respective sines and cosines to the given angles, and the given distances), then, because it is not possible to go from any place to the east without coming back the same distance to the west, nor to the north without coming back to the south the same distance, to get to the place of beginning, add all the northings together, and southings; eastings together, and westings: the sum of the northings should equal that of the southings; and the eastings, that of the westings.

There is an allowable error of one link to every three chains in the sum total of the distances.

CHAP. III.

Surveying with the Circumferentor.

The mode of surveying with this instrument is very simple and expeditious.

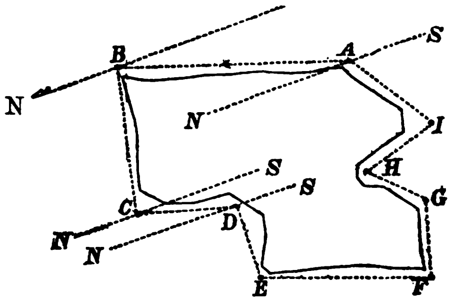
It matters not whether it is a road, pond, field, or wood, to survey; the same plan of taking the bearings and distances of the several sides must be adopted.

The chain and three flags only are required. Set your instrument at the first station, and a flag at the second, take the bearing of the second, and measure to it, taking such offsets upon the line as may be necessary; put the bearing in the centre column, and the line and its offsets above; at the end of this, draw a line in the book, and setting your instrument at the second station, and a flag at the third, proceed exactly as before, going round the whole of the ground to be surveyed till you come back to the place of beginning.

The same kind of check may be adopted with this instrument as with the theodolite, by taking at several stations (as you go long) the bearings to any fixed point, as a church spire, &c.

The following is an example of the survey, by the circumferentor, of the wood, given in chain surveying.

SURVEY OF WOOD.



OFFSETS.	CHAINS.	OFFSETS.
	343	to △ A
22	336	
20	200	
Wood + 26	100	
Bearing	N. 54° 50′ E.	
At △ I		
	273	to △ I
27	184	
26	150	
Wood + 17	080	
Bearing	S. 15° 10′ E.	
At △ H		
H—	223	— ×
26	215	to △ H
	205	
27	180	
Wood + 8	110	
Bearing	N. 42° 30′ E.	
At △ G		
	250	to △ G
17	225	
Wood + 16	025	
Bearing	S. 75° E.	
At △ F		

OFFSETS.	CHAINS.	OFFSETS.
	553	to △ F
24	534	
26	450	
43	300	
34	200	
Wood + 25	060	
Bearing	S. 20° W.	
At △ E		
	248	to △ E
Wood + 27	215	
70	105	
70	070	
Wood + 20	000	
Bearing	N. 89° 0′ W.	
At △ D		
15	310	to △ D
Wood + 23	300	
16	200	
46	050	
Bearing	S. 15° 10′ W.	
At △ C		
	463	to △ C
35	200	
Wood + 17	027	
Bearing	N. 77° 30′ W.	
At △ B		
	730	to △ B
Wood + 32	712	
42	600	
40	500	
37	430	
17	345	
28	210	
27	100	
Wood + 24	004	
At A on Base Line	N. 19° 0′ E.	to B

Explanatory Remarks.

In plotting from the Circumferentor Notes, place the Base Line, AB (see Plate No. 12), upon the paper in such a position as may best suit the shape and size of the plan, then, because it bears N. 19° E. at A, lay off the angle BAN., = 19° A N., or AS will be the meridian line. Measure 7·30 chains to B, and mark off its various offsets. Through B, draw a line parallel to A N.; and because the next line bears N. 77° 30′ W., at B, the end of the first line, lay off the angle N. BC = 77° 30′, and measure BC 4·63 chains. Through C, draw another line NCS., parallel to NAS. Then because the next bearing is S. 15° 10′ W., at C, lay off the angle SCD = 15° 10′, and measure CD = 3·10 chains. Through D, draw another line parallel to the meridian line, and as this bears to the north, make the angle NDE = 89°, counting the degrees from the north end; had the bearing been S. 89° W., then the degrees would have been reckoned from the south, as in the case of the preceding line CD. Proceed thus till you come to the last line, IA, the bearing of which is N. 54° 50′ E. Through I, draw the meridian line, and lay off the angle 54° 50′, as with the other lines, and measure the distance 3·43. The line IA, is the closing line; and you should now come back to the place where you started from. *Some little error, however, is unavoidable, where there are many lines.*

Having plotted the wood, divide it into triangles, and calculate the area.

Area of Wood:—

A.	R.	P.
4.	0.	37.

PRACTICAL EXAMPLES.

The following examples should be examined by resolving the bearings and distances as explained at page 147, and when corrected, plotted carefully, for the purpose of finding the areas.

Ex. 1. Required the area of a tract of land, whose bearings and distances are as follows, viz.:—1st, N. 15° 42′ E., 6·20 chains; 2nd, N. 52° 18′ E., 6·75 chains; 3rd, S. 78° 48′ E., 5·96 chains; 4th, S. 5° 51′ E., 4·84 chains; 5th, S. 49° 15′ W., 4·75 chains; 6th, S. 4° 57′ E., 3·98 chains; 7th, S. 71° 24′ W., chains; and 8th, N. 46° 18′ W., to the place of beginning.

Ans. To the 7th Bearing, the distance is 5·55 chains.
To the 8th Ditto ditto 6·81 „

	A.	R.	P.
And area of the whole	12.	3.	9.

Ex. 2. Given the following bearings and distances to find the area, viz.:—1st, N. 10° 21′ W., 4·50 chains; 2nd, N. 9° 48′ E., 5·20 chains; 3rd, N. 75° W., 3·00 chains; 4th, N. 20° 3′ E., 4·86 chains; 5th, S. 45° E., 5·20 chains; 6th, N. 3° 18′ W., 2·50 chains; 7th, E., 7·00 chains; 8th, S. 12° W., 3·94 chains; 9th, S. 43° E., 4·15 chains; 10th, S. 46° 57′ W., 8·20 chains; 11th, S. 29° E., 9·15 chains; 12th, S. 48° W., 4·56 chains; 13th, N. 19° W., 3·42 chains; 14th, S. 28° W., 8·54 chains; 15th, N. 53° W., 4·60 chains; and 16th, —„—, to the place of beginning.

Ans. 16th Bearing is N. 12° 18′ E.
And the Distance, 11·08 chains.

	A.	R.	P.
And area of the whole,	22.	3.	13.

CHAP. IV.

DIVISION OF LAND.

PROBLEM I.

To lay out a given area in a rectangular form, having the length to the breadth in a given ratio.

Rule. Divide the area by the product of the ratios; take the root, and multiply each side by its ratio.

Example 1. There are 2000 acres of land to be laid out in a rectangular form, whose sides are to each other, as 4 is to 5; what will their lengths be?

$m = 4$, $n = 5$ and $mn = 20$. $A = 20{,}000$ sq. chains.

$$\therefore x = \sqrt{\frac{20{,}000}{20}} = \sqrt{1000} = 31 \cdot 62 \text{ chs.}$$

$4x = 31 \cdot 62 \times 4 = 126 \cdot 48$ chs. $=$ one side
$5x = 31 \cdot 62 \times 5 = 158 \cdot 10$ chs. $=$ other side

EXAMPLE 2. One side of a rectangular field is double the other, what are the sides, when the area is 20. 0. 19. (A. R. P.) perches. *Ans.* 10·03 chs. and 20·06 chs.

EXAMPLE 3. A man has a farm of 150 acres, of a rectangular form, the depth of the farm is 50 chains. He is desirous of adding 50 acres to it, having the same depth, to make up 200. What will be the length of frontage of his farm, after the addition? *Ans.* Half a mile.

PROBLEM II.

When one of the sides is a certain length longer than the other.

To obtain the smaller side, square half the difference of the two sides, add it to the given area, and taking the root of their sum, from this root substract half the difference.

EXAMPLE. Given 464 acres, it is required to lay it out in a rectangular form, the one side being 6 chains longer than the other.

Ans. One side = 65·18 chs.; the other = 71·18 chs.

PROBLEM III.

From a given block of land, with parallel sides, the angle of inclination of the front and sides being given, to cut off a given area, by a line parallel to the sides.

RULE. Find first the perpendicular depth of the given *block,* by constructing the figure and measuring off the

perpendicular, then, as all parallelograms upon equal bases, and between the same parallels, are equal, divide the given area by this depth for the frontage required.

EXAMPLE 1. The concession road, of a certain township, bears N. 74° E., while the side lines bear N. 9° W. The length of the side lines is 66·66 chains, and the fronts of the lots are 30 chains. Required the frontage that must be taken, to cut off 100 acres, by a line parallel to the side lines.

The side lines, bearing N. 9° W., and the fronts, N. 74° E., the included angle, or angle of inclination, of the front to the sides, is 9° + 74°, or 83°.

The perpend. depth is found to be 66·16 chains

and 100 acres = 1000 square chains

$$\text{whence } \frac{1000}{66{\cdot}16} = 15{\cdot}12 = \text{the frontage required.}$$

Ans. 15·12 chains.

EXAMPLE 2. When the fronts of the lots bear S. 80° W., and the side lines N. 15° E., the side lines being 101·50 chains long, and the concession road frontage 20·00 chains, what will be the frontage required, to divide the whole lot between A and B, giving A 50 acres more than B, and and what quantity will each have?

Ans. { A, 117 acres, and 12·72 chains frontage.
B, 67 acres, and 7·28 chains frontage.

PROBLEM. IV.

From a given triangle, to cut off any given area by a line drawn from the vertex to the base.

Triangles, of equal altitudes, are proportional to their bases (see Theorem 17, page 15); therefore making A, the given area of the triangle; a, the part to be cut off; and x, the required portion of the base, we have

$$x = \frac{a.\ \text{base.}}{A}$$

EXAMPLE 1. There is a Gore of land between two townships, whose area is 425 acres, and base is 85 chains. It is required to cut off 400 acres by a line drawn from the vertex.

As 425 : 400 : : 85 : (x) chains.

Where $x =$ length of new base, $=$ 80 chains.

EXAMPLE 2. From a Gore of land, having a base of 60 chains, containing 125 acres, required the base, to cut off 50 acres. *Answer* 16 chains.

EXAMPLE. 3. From a triangle, with a base of 74·54 chains, containing 35 acres, required the base to cut off 860 square yards. *Answer* 8½ yards nearly.

CHAP. V.

COLOURING MAPS.

The measured lines, if put in, which is however seldom the case in finished plans, must be in lake, drawn in with a steel drawing pen, done in the same way as the boundaries of the several properties, which are to be in Indian ink.

The fields should be coloured with Italian pink, mixed with indigo, laid on very lightly, so that all the roads, houses, trees, hedges, &c., and smaller objects, may stand out in strong relief against them. No two fields should have exactly the same tint: by varying the proportions of the indigo and Italian pink, and adding a *little* crimson lake now and then, this may be easily done.

The trees and hedges should be done with Indian yellow and indigo, of a stronger tint, to stand out, as it were, from the fields. A light shadow in sepia may be advantageously thrown in to increase the effect.

The water should be put in with cobalt, in waves decreasing in width as they increase in strength, till a strong edging of Prussian blue gives depth to the whole; a streak of white should in all cases be left in the centre.

For roads, the only really good quiet colour is Roman ochre.

Brick houses are coloured with crimson lake; *wooden* ones with Indian yellow. Burnt sienna makes a good *gravel*, and burnt umber and brown madder do well for *ploughed land.*

Gardens are represented by small rectangular divisions,

coloured with a brighter tint than the fields, which should always be of a more sober hue; the indigo predominating in the latter, the Italian pink in the former. These divisions should be laid in at once with a brush, having no ruled black lines to show their limits; care must, at the same time, be taken to have but very little colour in the brush, otherwise the edges will dry hard.

Copying Maps.

There are various methods adopted in copying maps.

The quickest is that of putting a piece of tracing paper over the map that is to be copied, and tracing out the lines.

This tracing paper is then pasted down *by its edges only* upon some clean paper.

Another quick plan is that of placing a clean piece of paper under the map that is to be copied, and with a fine needle pricking through all the lines upon it, wherever there are any corners. The marks of the needle are then joined carefully *by a pencil*, and the map is in this state examined with the original, and the pencil marks, if correct, are put in, in ink. The latter is decidedly the better method, where the plan is large, and when there are but few houses; but where it is complicated, the former method should be adopted.

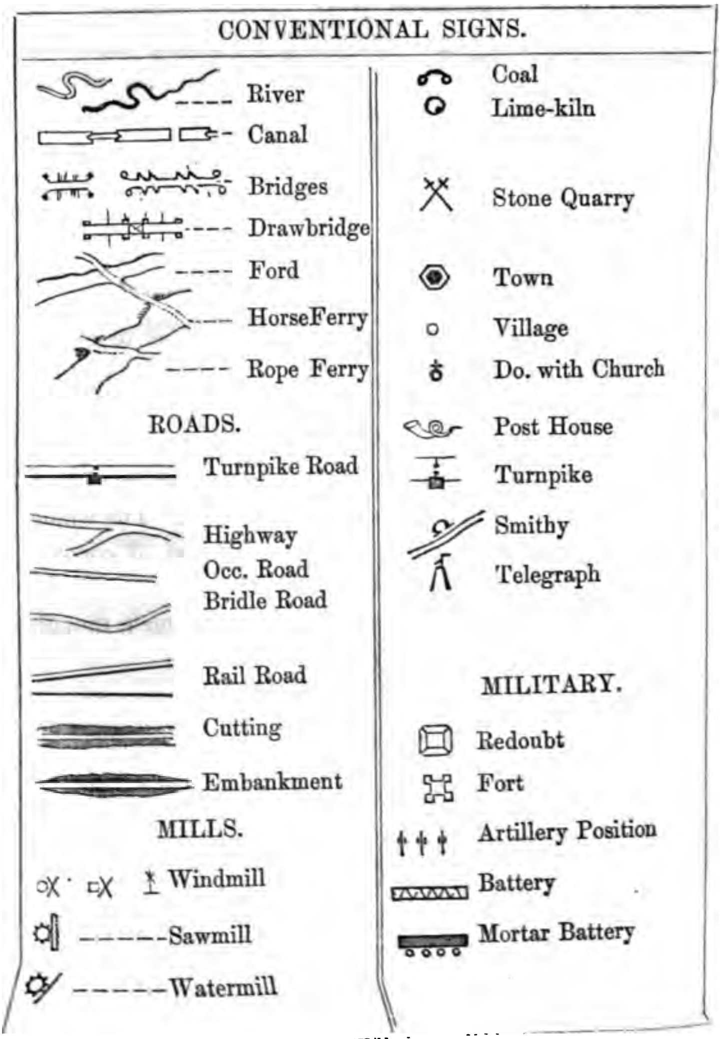
Should it, however, be necessary to have the copy made upon drawing-paper, after the tracing is made, which should in this case be done very carefully, it should be *placed* over the drawing-paper, and having a piece of

transfer-paper under it, between it and the drawing-paper, every line upon the tracing-paper should be gone over carefully with some blunt point, marking especially the corners of the buildings. On taking the tracing-paper off, an exact copy will be found beneath, which must then be drawn in, first in pencil, afterwards in ink, and the transfer marks carefully rubbed out.

When the Plan is to be Enlarged or Reduced.

The simplest and easiest method, perhaps, is to divide "the map, plan, &c., to be copied" into squares, and by constructing a like number of squares on the drawing paper, according to the required proportion, to draw within these steadily with a pencil the several lines that are found in the corresponding squares of the original. The whole should afterwards be carefully examined, and, if correct, inked in. Sometimes the pentagraph is used, it is not so correct, especially when plans have to be enlarged, though it is useful for reducing them.

The following conventional signs, being those most in use, have been added for the benefit of the reader.



MINES.		BOUNDARIES.	
☉	Gold	— — — —	of a County
☽	Silver	—.—.—.—	of a Parish
♃	Tin	- - - - - - - -	of a Township
♀	Copper		
♄	Lead		
		△	Station Point
☿	Quicksilver		

CHAP. VI.

The following Remarks on Plotting will be found useful.

BEFORE commencing to plot, it is always requisite to consider carefully the shape of the plan to be plotted, its size and character, and the most desirable position to place it upon the paper, so as to admit of the best vacant space for the insertion of the heading or title, with the usual specification, that should accompany it.

Before commencing your plan, take care also to have the paper properly stretched upon a drawing board,* if the

* One of the best methods of laying down drawing paper is this. Wet the paper with a sponge, working from the centre either way, on the side that you are *going to use*, until the paper has been sufficiently stretched, the

size of the plan will admit of it, and finish the whole plan before taking the paper off the board. At the bottom of the paper, make a scale of the required proportion, carefully dividing it into tenths and hundredths as the case may be, and let all *long* lines upon the plan be measured off this scale. The *short* ones, that is, lines of offsets, lines of distances less than tenths, may be taken off the ivory scale, from which the scale upon the paper was first obtained.

Having made the scale, lay down your base line very accurately, and draw it carefully in with lake, marking the various stations upon it and its total length. Then take, with the compasses, the various lengths of the sides of the several triangles, of which the survey is composed, and lay off the different points of intersection, testing rigorously as you proceed, the *constructed*, with the *measured* lengths of the respective *check-lines.*

Do all this *before* an offset is put in, unless the offset be afterwards used as the point of a more convenient base line for another triangle.

---

beginning with the longest side, place a straight-edge upon it, about half an inch from the edge, and leaning hard upon the straight edge; turn up the edge of the paper by running the back of a knife *under* the paper against the straight edge, and run the glue brush, taking care not to have the glue too thick or too thin, upon the board *under* the paper, then, still keeping the straight-edge down, run the back of the knife over the paper close against the straight-edge, which will make the paper adhere partially to the board, then, taking a clean piece of paper, put it over the drawing paper, and with the back of the knife rub the glue hard on, until the glued edge adheres closely to the board. Then serve the opposite side of the paper the same way, taking care, in placing the straight-edge, to press well the straight-edge outward, so that the paper shall be as tight as the wet will allow it, before you glue down the second side. If this is carefully seen to, when the four sides have been glued in succession, the paper when dry, will be as tight and as smooth as a drum,

When this part of the plotting is found correct, draw the lines in very plainly with lake.

In marking off the several distances on the base line use one of the long scales, and placing it close against the given line, prick off with a fine needle the proper distances, and round the points, as centres, draw a small circle. Do this also in determining the points of inclination of the sides of the triangle.

Having finished these subsidiary lines, as they may with propriety be termed, proceed to the laying off the offset points.

The best method of doing this, is to place the long scale above referred to, close against the given line, having the zero points of each coinciding, and get an assistant to read off the several distances thereon, whence offsets are taken, first going through the right offsets, then the left. An offset scale is now necessary, which is a small scale of two inches, divided in the same way as the long one, but the zero points being either edge of the scale. This is placed against the long scale, and the lengths on the measured line are determined by the long line, while the distance from any point, or offset therefrom, is determined by the offset scale; this latter point is alone marked. Practice and care will ensure considerable rapidity, as well as accuracy, in doing this.

When the scale is 2 or 4 chains to the inch, any offset, less than 10 links, must be done by the hand.

With reference to the division of the scales—the scales used for horizontal delineations are generally 2, 3, or 4, chains to the inch, or 20, 30, or 40 chains.

The division of the common and vertical sections is generally *5 or 50* feet, 10 or 100 feet to the inch.

LEVELLING;

Part the Fourth.

ITS NATURE AND OBJECTS.

CHAP. I.

LEVELLING is the art of representing the inequalities of the earth's surface, and of determining the relative heights of any number of points above or below a line, *equidistant, at every point, from the centre of the earth.* This line is what is understood by the term—*a level line;* it is that line which is assumed by water when at rest.

The instrument, used for the purpose of levelling, is called a SPIRIT LEVEL.

The Spirit Level.

This instrument is merely one portion of almost every other instrument, carried out to its greatest practical perfection. The bubble, which in most instruments forms only a *subordinate* part in the construction, is in this the *chief,* the only object of the instrument being to obtain a practical tangent to the earth's surface, or to place the line of collimation of the telescope in a truly horizontal line.

This instrument consists, like the others, of its parallel

plates, with their two pairs of conjugate screws, of its telescope, and its spirit level beneath. The telescope also, as in the case of the theodolite, has its milled-head adjusting-screw for the object-glass; and the moveable eye piece for neutralizing the parallax. The cross wires, however, are not arranged the same way as in the theodolite; sometimes one horizontal and two perpendicular wires are used instead.

The spirit level is furnished with its capstan-headed screws, for making it parallel to the axis of the telescope, vertically and laterally.

But in this instrument there is one contrivance which the theodolite does not possess—that of raising or depressing one of the Y's, or supports, on which the telescope rests, so as to have the axis of the telescope always at right angles to the axis of the instrument.

Adjustments.

There are two principal adjustments necessary in this instrument: the first to make the level and the telescope parallel; the second to make the axis of the telescope always at right angles to the axis of the instrument; in other words, to secure the line of collimation being perfectly level in any portion of a complete revolution of the instrument. The first adjustment depends upon what instrument is being used, and varies in each. There are, for instance, the Y level, Troughton's Improved, the Dumpy, all good levels, but differently adjusted. The second is almost the same in every instrument. It is thus arranged:—

Set the telescope over any pair of conjugate screws, and make the *bubble* level; turn the instrument, till the tele-

scope be over the conjugate pair: level it in this position; then turn it back to the first pair, and correct for any error that may have arisen from the last levelling, and continue till the bubble be central over the two pairs of conjugate screws; then turn the instrument one half revolution round, and, if the bubble still remain in the centre, the instrument is in adjustment; if not, the error can only be occasioned by the axis of the bubble, or which is the same thing, the axis of the telescope not being truly perpendicular to the centering of the instrument.

To correct this error, in the case of the Y level, raise or depress the moveable (Y) support by the milled-headed screw beneath, until the bubble be brought half-way to its proper position, and correct for the other half by the parallel screws. By repeating the correction two or three times, the greatest accuracy will be obtained.

It is necessary to examine the adjustment every morning before starting, and it should be seen to at every observation, though it will scarcely require re-adjusting the same day, I should observe, that there is, or ought to be, a cap over this adjusting (Y) screw which should be carefully kept on.

Levelling Staves.

These are generally made twelve feet high, divided into feet, and again into tenths of a foot, and subdivided for facility of computation, into hundredths. The method of arranging this subdivision, constitutes the difference between the several staves in use. The feet are distinguished by *large red figures*—the tenths are in black.

There are Sopwith's, Gravatt's, the Diagonal Staves, &c.; all having their admirers.

CHAP. II.

CURVATURE AND REFRACTION.

Correction for Curvature.

For long distances, the curvature of the earth must be taken into consideration, as well as the density of the atmosphere. To correct the former, square the distances measured, and divide by the diameter of the earth in terms of the distances.

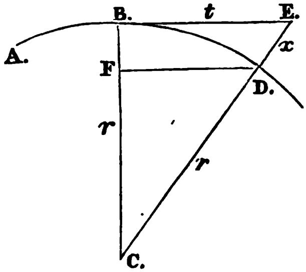
EXAMPLE. What is the correction for curvature for one mile distance? *Answer* 8 inches, or $\frac{2}{3}$ foot.

And because this correction is always equal to the distance squared, divided by the constant quantity (the diameter of the earth) it will vary as the squares of the distance; therefore, for one mile, it is equal to $\frac{2}{3}$ foot; for 2 miles, $\frac{2}{3}(2)^2$ feet, or $\frac{2}{3}(4)$ feet; for 3 miles $\frac{2}{3}(3)^2$ feet, or $\frac{2}{3}(9)$ feet, 6 feet.

This correction, when the level is obtained by the theodolite, must, to obtain the true height, be added to the apparent height.

The refraction, or the correction for density, which may be taken as $\frac{1}{7}$ of the correction for curvature, must be *subtracted* from it.

Example of applying this correction.



Placed a spirit level at any point B, on the earth's surface, and found the point E, at 3 miles off, to be on an apparent level with the point B. What is the comparative height of the object E?

Now, BE is the apparent level, and BD the true level, B and D being points equidistant from the earth's centre. DE (x) is the height of E above B, which, in feet, equals two-thirds the distance (BE, in miles)$^2 = 3^2 \times \frac{2}{3} = 9 \times \frac{2}{3} = 6$ feet, the height of the object E above B.

To correct for refraction, the object observed at a distance of 3 miles was apparently level with the instrument, but the correction for curvature was 6 feet, now the correction for curvature being one-sixth of the height, $\frac{1}{7}$ of $\frac{6}{1} = \frac{6}{7}$ feet $= 10\frac{2}{7}$ inches, and therefore 5 feet $1\frac{5}{7}$ inches $=$ the true height of the object, allowing for *both* corrections.

EXAMPLES.

1st.—The observed heights of three objects, at a distance of 4, 6, and 8 miles (calculated from observation taken by the theodolite), were found to be respectively, 24, 25, and 28 feet. What are their true heights?

Answer 33 feet 2 inches; 45 feet 7 inches; and 64 feet 7 inches.

2nd.—Found the angle of elevation of the spire of a church, which was 420 chains 75 links off to be 1° 10′. What is its real height above the point of observation?

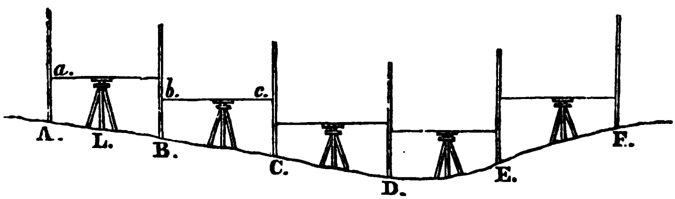
Answer 581 feet, 9 inches.

CHAP. III.

THEORY OF LEVELLING.

To find the difference of levels between several points, or to trace a SECTIONAL LINE *of the inequalities of the earth's surface.*

Let ABCDE be the line to be traced. Set the level (L) between the object, and read off the height A*a* and that of B*b*, the difference between A*a* and B*b* will be the number of feet that B is higher or lower than A*a*; if B*b* be greater than A*a*, the point B will be lower (by this difference) than A*a*; for the height, read off by the level staff, is the number of feet that each point observed is *beneath* the level of the line of collimation of the telescope—hence, where there is a number of points beneath the same level line, the greater the reading of the staff, the lower this point must be.



Then, because, in the first observation, the height at B (read by the level staff) is greater than that at A, the point B is lower than the point A. Again, in the second example, where, *it* must be observed, that another line of

collimation is taken, because the height by the staff at C is greater than that at B, the point C is lower than B. In the third observation, also, D is lower than C, and C being lower than B, and B than A, the ground falls thus far. At the fourth observation, however, because the height at D is greater than that at E, the point D is lower than E, and therefore, E being higher than D, the ground rises to E, and as the reading at E is greater than at F, it goes on rising to F. The relative heights of the two ends of the line, at A and F, depend upon whether the ground falls, more or less, from A to D, than it rises from D to F.

Now, the difference between the reading at B and A, in the first observation, added to the difference of readings at C and B, in the second observation, plus this difference between D and C, in the third, as there is a continued descent to the point D, will give the actual fall from A to D, or the number of feet, that the point D is lower than A. In the same way, the sum of the difference of readings of D and E, and of E and F, in their respective observations, will be the number of feet F is higher than D; if, therefore, the fall from A to D be greater than the ascent from D to F, the difference will be the actual fall from A to F, or the number of feet that the point A is higher than the point F.

This is the principal object of levelling. It is very simple in theory, but in the carrying out of the practical operations, great care is necessary. In this, as in most things which are of a simple character, and which do not admit of checks in the course of the work, errors are very likely to creep in imperceptibly.

As the necessary calculations for curvature and refraction

would be exceedingly tedious, in extensive operations, the following method renders them altogether unnecessary.

Set the level *halfway* between the objects, as nearly as *the eye can tell*, and the corrections for both become equal and opposite, and therefore neutralize each other.

CHAP. IV.

TRIAL LEVELS.

Having determined upon the general line of route, the line is marked down upon the Ordnance map, and the several points, where the roads are crossed, are carefully measured from the scale, and determined upon the ground.

The levels are then taken, as near as possible to this direction—the error of deviation being always confined to the intervals between the roads—the relative heights of these points of the roads being always ascertained, and bench marks taken near. The inclination of the ground on the right and the left of the line, is also, in the first trial level, carefully marked so that the engineer may know on which side of the levelled line to deviate, when he is in want of a piece of cutting, or an embankment.

The trial level, however, is, after all, but very rough work, and serves only as a general check upon the correctness of the subsequent levels.

CHAP. V.

CHECK LEVELS.

Are levels taken for the purpose of determining a second time, the heights between several distant points, which agreeing with the first, becomes a strong proof of the correctness of the work in detail.

CHAP. VI.

FINAL LEVELS

Method of levelling and of keeping the Field Book.

Having determined upon the point of commencement, select some fixed point, as near to it as possible, the height of which when taken may become a mark of reference for any subsequent levelling. This is called a *bench mark*. The *best* bench marks are hinges and hooks of gates, mile stones, nails driven into trees, &c.

Place your level about half way between this point and the next onward station, and fixing the legs firmly in the ground, set the instrument level, and observe the height read off by the staff when placed upon the bench mark, *this* observation is called a back-sight, or backset. Turn

the instrument round to the starting point or 0·00 of the levelling and read off the height there. This is an intermediate, as not being a connecting-link in the consecutive series of backsets and foresets. Lastly, read off the height at the forward station, which is termed the foreset, taking care, *before each of these observations, to see that the bubble is duly in the centre of the tube.* Now take up the level, and place it, as before, between the next two stations, and so on, observing the back and forward readings in every case, and taking, on the way, such *bench marks* as may appear desirable for the purposes of reference hereafter. These bench marks should be of a permanent character, *near* to the line, and in conspicuous places.

In taking these observations great care should, in all cases, be observed, and due attention paid on the part of the surveyor, to the non-existence of parallax.

The staff-holder, also, incurs considerable responsibility as all the care on the surveyor's part would be neutralized by inattention in the placing or moving of the staff. At every station the staff has to be read off twice, in opposite directions, and great care is requisite in turning it round. A piece of slate, or board, is sometimes used by the staff-holder for that purpose, so as to keep the staff always in the same point. Much error also arises from the staff not being held perfectly upright; there is some difficulty in keeping it so, and men are apt to become tired and careless. The wind, too, will often disturb it.

The following Example of keeping the Field Book will, it is hoped, enable the learner to understand clearly the principle on which all levelling is conducted.

Back.		Inter.		Fore.		Rise.		Fall.		Reduced Levels.	Distance	Rema
9	96									200·00	B. M.	On first step o house, on which
		10	85					0	89	199·11		Centre of road f to Mordiford.
		4	81			6	04			205·15	0·67	Bank of field.
				6	38			1	57	203·58	1·50	Road × at 0·00
3	49			7	25			3	76	199·82	4·55	Hedge ×, 4·34.
2	57			10	64			8	07	191·75	7·00	
4	46			6	54			2	08	189·67	11·00	Mill pond × 15·00.
4	63			3	12	1	51			191·18	12·10	On bank of mill
6	33	7	33					1	00	190·18		Surface of water
				2	46	4	87			195·05	16·00	
10	18			1	08	9	10			204·15	17·50	
11	94			3	53	8	41			212·56	21·00	Hedge ×, 23·33,
4	48			4	75			0	27	212·29	25·00	Hedge ×, 26·72.
6	08			6	43			0	35	211·94	28·00	
3	28			9	03			5	75	206·19	30·00	Road × 30·37 &
6	75			3	14	3	61			209·80	31·65	Centre of road f to Worcester.
11	89	5	84			6	05			215·85	B. M.	On lower hinge posite Crown
				1	83	4	01			219·86	35·50	Hedge ×, 33·52.
10	40			3	14	7	26			227·12	37·24	Lane × at 37·25
6	20	6	52					0	32	226·80		Centre of lane.
				1	60	4	92			231·72	39·50	Hedge × at 41·0
7	03			0	73	6	30			238·02	42·70	Hedge × at 44·0
6	25			1	28	4	97			242·99	45·00	
8	13			2	67	5	46			248·45	47·00	
8	32			1	50	6	82			255·27	49·00	
8	28			1	48	6	80			262·07	51·00	
140	65			78	58	86	13	24	06	200·00		
78	58					24	06					
62	*07*					62	07			62·07		

The first level taken is a backset, 9·96, the staff being held on the step of a house adjoining the line, in the road from Hereford to Mordiford. This point was assumed as 200 feet above a common *datum* line, to which line all the subsequent heights are referred, The next observation was 10·85 centre of road; now, because 10·85 is greater than 9·96, it shows that the point at 10·85 is lower than that at 9·96; deduct, therefore, 9·96 from 10·85, and put the difference 0·89 in the column of falls (because the ground falls there); again, because the starting point was 200 feet above the datum line, and the second point 0·89 lower than the starting point, deduct this 0·89 from 200 feet, and you have 199·11 as the height, or the reduced level of this second point above the datum line. This second point is the centre of the road. The next point reads only 4·81, being, therefore, 6·04 higher than the second point, and must be placed in the column of "rises"; add, therefore, 6·04 to 199·11, and you obtain the height of this third point. The next point which is a foreset (after the reading of which the instrument will have to be moved onwards) is 6·38, or 1·57 lower than the last; place 1·57 in the column of falls, and deduct it from 205·15, making the reduced level 203·58.

Considering, therefore, each backset and foreset, with as many intermediates as may be wanted between them as the links of the chain, find the difference between every observation and its subsequent one—if the latter be greater, it falls; if smaller, it rises—place these in their proper columns; then, from each preceding height or reduced level, deduct the falls and add the rises of the following observation as the case may be, to obtain the reduced level *of that observation.*

The proof of the correctness of these calculations is obtained by adding the backsets together, and the foresets together, and finding the difference between the two sums. Find secondly, the difference between the sums of the rises and falls; and lastly, the difference between the first and the last reduced levels; these three differences should be equal, and this serves as a check or proof of the previous calculations being correct. Thus the backsets are 140·65; the foresets 78·58; the ground rises 62·07 feet; the rises are 86·13; the falls, 24·06; the difference between which is also 62·07 feet; the falls being the smaller, the height at starting was 200 feet; the last height is 262·07, or 62·07 feet higher than the first: the work therefore is correct.

The annexed field notes, containing only such information as is obtained in the field, are given for the student's practice. They must be resolved into their rises and falls, and reduced to their heights above the datum line, as in the foregoing example. The assumed height is given, 200 feet above the datum line: and the calculations are to be referred to that. The heights of some of the bench marks are given throughout, as checks upon the student's calculations. The safest check, however, is finding whether the three differences before-mentioned are the same.

FINAL LEVELS,

TO BE REDUCED AND PLOTTED

TO A SCALE OF

SIX CHAINS TO THE INCH, HORIZONTAL;

AND

FIFTY FEET VERTICAL.

Back.	Inter.	Fore.	Reduced Levels.	Distance	Remarks.
6 61			200·00		Surface of rails at junct Eastern Counties R
	6 43			B. M. No. 1	Stake by side of railw
	7 20				On slope of cutting.
		0 36			
8 69	4 84			1·20	On top of cutting.
	0 89			B. M. 2	On top of fence of marked 0, and near post.
		4 76		1·40	
5 47	4 91			3·50	Near side of road.
	5 18			4·10	Centre of road, see × No. 1.
	6 08			4·65	Other side. Road × and 450.
	6 95		208·70	B. M. 3	On lower hinge of of gate, far side of
		6 35		8·50	Near side of hedge. B
3 29					
	6 43			8·90	Far side.
		6 14		11·10	
6 53					
	5 10			12·00	Near side of hedge on
	4 26			12·50	Far side. H at 12·2
		4 76		13·90	
3 00		5 63		21·00	This side. H at 21·3
6 43					
	6 25			24·60	Other side.
	5 29			25·00	This side of road.
	5 82			25·75	Centre of road, see × No. 2.
		3 72	208·30	B. M. 4	Lower hinge of left po line, and near side Road crosses at 2 26·00.

Back.	Inter.	Fore.	Reduced Levels.	Distance	Remarks.
3 90			208·30		
		4 83		26·30	Far side of road.
1 85					
	4 58			30·08	
	4 76			33·50	This side of hedge. H at 33·70.
		5 35		34·00	Far side of hedge.
4 57	4 71			36·09	Hedge × 37·80.
		4 72		38·00	Far side of hedge.
4 29	4 55			40·00	
		5 70		42·25	Near side. H, 42·40.
4 32	4 75			42·90	Far side.
		4 71		45·10	
3 00	5 50			53·00	Near side.
		4 97		53·60	Far side. H, 53.40.
3 10	4 80			56·00	Near side.
		5 02		57·00	Far side. H, 56·40.
0 30	5 00			68·00	Near side of hedge.
	7 45			69·85	Near side of road.
		5 00		B. M. 5	Lower hinge of gate, right of line.
3 15		5 69		71·60	Centre of road } road 71·87
4 87	6 00			72·60	Far side of road } and 72·40.
		6 92	188·74	77·20	Near side of hedge. H, 77·50

Back.	Inter.	Fore.	Reduced Levels.	Distance	Remarks.
4 33			188·74		
	4 45			80·00	1 Mile
	6 55			2·45	H at 2·60
	6 48			2·80	
		7 28		7·10	H at 8·00
4 56	4 76			8·40	
	7 80			12·00	H at 13·00
		8 94		13·60	
1 87	3 65			15·00	H at 17·47
	5 20			17·58	
	8 26			21·00	H at 21·35
		11 60		21·50	
5 92	5 05			22·00	
	6 50			22·60	
	4 38			23·50	
	7 65			26·82	H at 26·90
		8 05		27·10	
1 27	6 80			29·40	H at 29·60
		9 65		29·85	
2 57	5 95			36·00	H at 36·40
		5 92	157·82	37·00	

Back.	Inter.	Fore.	Reduced Levels.	Distance	Remarks.
2 65			157·82		
		7 20		40·78	Road at 41·00 and 41·30
5 82	6 52			41·15	Centre of Road see × Section
		4 09	155·00	B. M. 6	Upon notch in side of gate
3 80		7 69		42.00	post, left of line.
0 96		9 79		46·16	
2 00		5 19		47·86	H at 47·71
2 77	1 15			49·80	H at 50·00
	3 28			50·60	
		6 72		52·50	
3 69	3 98			54·00	
		7 90		59·70	H at 59·80
4 27	4 45			60·00	
		8 11		64·30	
1 45		8 10		70·00	H at 70·30
3 58	4 25			70·80	
	4 74			B. M. 7	on post of new bridge over
	6 10			72·20	stream; marked thus
		5 07		73·80	Stream crosses at 74·00, & 74·50
5 25	8 15				Surface of water in stream
	5 51			74·60	
		0 99	123·21	76·90	H at 77·40

Back.	Inter.	Fore.	Reduced Levels.	Distance.	Remarks.
7 50			123·21		
	4 85			77·50	
		0 67		80·00	2 Miles
4 32	3 50			1·00	Road at 1·40 and 1·80
	5 44			1·60	Centre of road, see × sect No. 5 a.
	3 11			2·00	
	2 38		131·98	B.M. 7a	
		4 12		2·80	
9 95	5 92			4·00	
		4 37		670	H at 6·85
7 50	3 63			B.M. 8	on trunk of old tree in hedge
	7 05			7·00	
		0 97		10·00	
5 12	4 28			12·14	
	4 85			14·00	
	3 17			16·10	
		2 47		18·60	H at 18·70
5 28	4 70			19·00	
		7 40		23·00	
5 02	5 81			23·50	Centre of road, see × section 6
	6 24			24·00	Road crosses at 23·20 & 23·8
		4 70	143·20	26·00	

Back.	Inter.	Fore.	Reduced Levels.	Distance.	Remarks.
3 49			143·20		
	5 62			29·00	
	4 38			29·40	H at 29·20
		3 10		34·00	H at 34·10
5 66	6 47			34·40	
	4 63			37·00	H at 37·30
		3 92		37·60	
3 66	8 80			41·00	H at 41·40
	9 19			B.M. 9	Lower hinge of gate, right of
		9 40		41·50	line; left post marked
2 14	3 74			44·00	
	6 28			47·00	H at 47·70
		6 24		48·00	
0 00	3 20			49·10	H at 50·50
		5 95		50·70	
3 50	4 80			53·00	H at 53·70
	6 47			54·00	
		6 95		56·00	
4 14	5 33			59·40	H at 59·60
	5 72		127·25	60·00	Upper rail of fence marked
		2 98		B.M.10	O in line

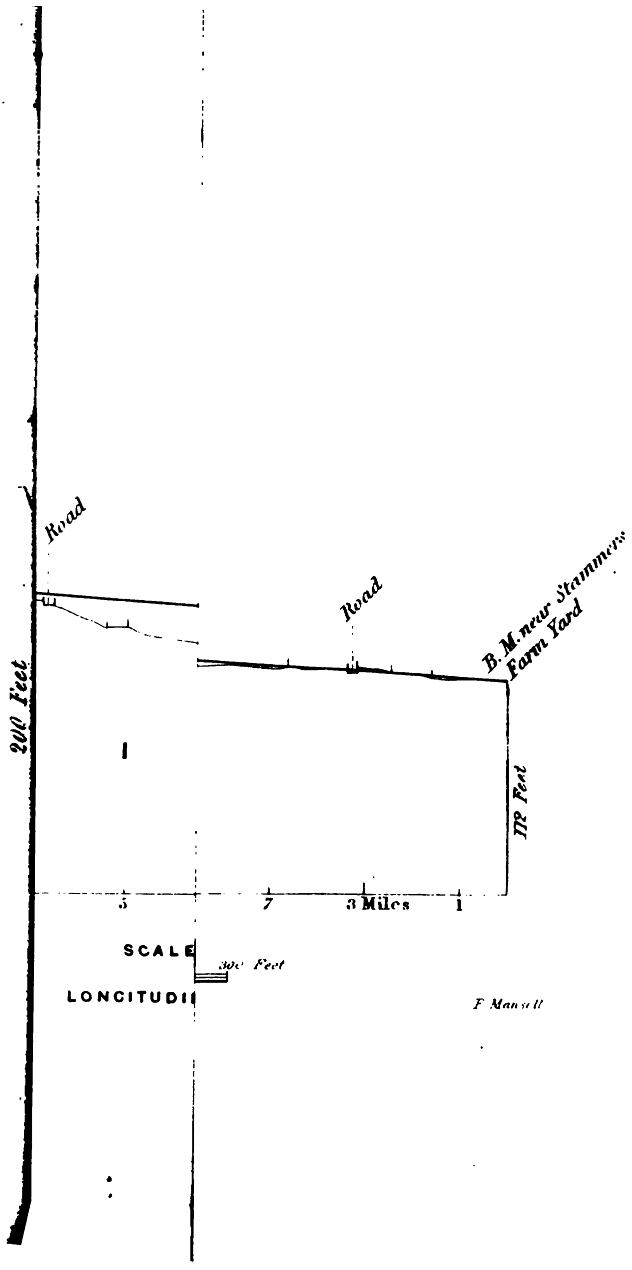
Back.	Inter.	Fore.	Reduced Levels.	Distance.	Remarks.
0 50			127·25		
	7 48			61·90	
		6 51		65·00	
4 03	5 59			71·00	H at 71·30
		5 65		72·00	
4 50	5 10			74·10	
	4 78			78·00	This side of road
		6 46		78·45	Centre of road.—See × Sec No. 7 *a**
5 72		2 04	121·34	B.M.11	on trunk of large tree, notcl near side of road
2 04	4 10			79·00	Road at 78·10 and 78·90,
	5 00			80·00	3 Miles
		6 76		2·00	H at 2·35
4 26	4 29			2·50	
	5 57			3·60	
	6 47			6·00	H at 6·80
	7 43			7·00	
		7 45		10·09	
4 18		4 96		14·46	H at 14·35
3 79		4 11	112·33	B.M.12	on staple of left post in St mer's Farm-yard.

* *The Cross* Sections referred to in these levels have been omitted in the p

These notes must be filled up by the student himself; and then plotted to a scale of 6 chains to the inch, horizontal, and 50 feet vertical, and compared with the accompanying section.

The strong black line upon this section is an arbitrary line, representing the surface of the rails.

FINIS.



Road
Road
B. M. near Stammers Farm Yard
200 Feet
112 Feet
5
7
3 Miles
1
SCALE
300 Feet
LONCITUDI
F Mansell